Radiotelemetry Observations of Migrating Adult Sockeye in the Fraser and Thompson Rivers

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ABSTRACT

Fretwell, M.R. and B.G. Dane. 1987. Radiotelemetry observations of migrating adult sockeye in the Fraser and Thompson rivers. Can. Ms. Rep. Fish. Aqu. Sci. 1939. __ p.

Migrating adult Adams River sockeye salmon (Oncorhynchus nerka) and Thompson River steelhead (Salmo gairdneri) were fitted with internal radio transmitters and tracked in the Fraser and Thompson rivers, to establish the feasibility and develop techniques for using radiotelemetry to study the behaviour of migrating adult salmonids. Tracking was undertaken by aircraft, vehicle and on foot to monitor overall migration rates and behaviour at proposed CN railway encroachment sites.

Delay in sockeye migration following tagging averaged 17 hours. Migration rates increased progressively as the fish moved upstream through the Fraser and Thompson rivers while river gradient and water velocities decreased. Delay was observed between Black Canyon and Scuzzy Rapids which includes Hell's Gate, and through the Thompson Rapids. Detailed tracking indicated that fish frequently crossed from bank to bank. Visual observations were made of sockeye migrating along various types of natural banks and along existing encroachment sites. Steelhead tagged near the Fraser-Thompson confluence did not move appreciably during the period of the study.

Key words: sockeye salmon, radiotelemetry, adult migration, Adams River, Fraser River, Thompson River.

RESUME

Fretwell, M.R. and A.G. Dane. 1987. Radiotelemetry observations of migrating adult sockeye in the Fraser and Thompson rivers. Can. Ms. Rep. Fish. Aqu. Sci. 1939. __ p.

Dans le but de confirmer la possibilité d'utiliser la radiotélémétrie et d'en développer les techniques pour étudier les moeurs des salmonidés adultes émigrant dans les rivières Fraser et Thompson, des transmitteurs-radio internes ont été placés sur des saumons rouges (Oncorhynchus nerka) adultes émigrant dans la rivière Adams et sur des truites arc-en-ciel (Salmo gairdneri) adultes émigrant dans la rivière Thompson. La filature a été faite par avion, en voiture et à pied pour étudier les taux de migration et les moeurs des salmonidés aux emplacements où les rives pourraient être altérées par les rails de la voie de chemin de fer de la compagnie CN Railway.

Le retardement de la migration de saumons rouges après l'etiquetage est de 17 heures en moyenne. Les taux de migration augmentaient progressivement à mesure que les poissons remontaient le cours des rivières Fraser et Thompson, alors que la pente et la vélocité des eaux diminuaient. Un délai a été observé entre Black Canyon et les Rapides Scuzzy qui comprennent Hell's Gate, et à travèrs les Rapides Thompson. Une filature précise a révélé que les poissons traversaient fréquemment la rivière d'une rive à l'autre. Des observations à vue ont été faites des saumons rouges émigrant le long de différents types de rives naturelles et d'emplacements où les rives avaient déjà été altérées par la voie de chemin de fer. Les truites arc-en-ciel étiquetées près de la confluence des rivières Fraser et Thompson n'ont pas démontré de migration appréciable pendant la durée de l'observation.

Mots-cles: saumon rouges, transmitteurs-radio, migration d'adultes, Rivière Adams, Rivière Fraser, Rivière Thompson.

1.0 INTRODUCTION

The twin tracking of CN Rail's main line through the Fraser River and Thompson River valleys is expected to result in some encroachment on the rivers. Significant populations of anadromous salmonids utilize the Fraser and Thompson rivers for migration, spawning, incubation and rearing. The encroachment may have adverse effects on fish stocks such as by increasing river velocities in the affected sections. Increased river velocities increase the energy expended by the fish during migration, and thus potentially deplete finite energy reserves to the extent that the reproductive success of the fish is impaired.

The populations of anadromous salmonids utilizing these rivers include pink salmon (Oncorhynchus gorbusha), sockeye salmon (O. nerka), chinook salmon (O. tshawytscha), coho salmon (O. kisutch) and steelhead trout (Salmo gairdneri). Swimming capabilities of fish are determined by a number of biological factors including size, species, sex, and age, as well as physical factors such as water temperature and characteristics of water flow. Among those listed above, the pink salmon is believed to be the species most severely affected by alterations of bank configuration or river velocities, as a result of encroachment. This species appears to be the least capable swimmer of the fish concerned (Brett, 1982). In addition, it may have the most rigid migration schedule due to the fact that, of the Fraser River pink salmon populations the Thompson and Seton pinks migrate the furthest to spawn. For this reason, the Thompson River pink salmon population was selected as the primary study population for a "worst case" assessment of the potential impact of twin tracking encroachments upon migrating salmonids. The current study of 1982 Adams River sockeye and Thompson River steelhead was undertaken for the purpose of developing techniques and establishing the feasibility of using radiotelemetry for studying the migration behaviour of salmonids in the Fraser and Thompson rivers. It was intended that the resulting techniques could be applied in the study of adult Thompson River pink salmon migration, proposed for 1983. In the future, a comparison of migration behaviour of sockeye and pinks may provide some insight into the differences between pink and sockeye salmon physiologies.

Field work for the current study was conducted from September 27 to October 20, 1982. This study was the cooperative effort of Department of Fisheries and Oceans (DFO), Ministry of Environment B.C. Fish and Wildlife Branch (MOE BCFW),

International Pacific Salmon Fisheries Commission (IPSFC) and CN Rail through its consultant D.B. Lister and Associates.

2.0 RADIOTELEMETRY STUDIES

Several aspects of salmonid migration were proposed for study by tracking fish implanted with miniature radio transmitters. Periodic locations of migrating fish as they moved upstream, would provide migration rates along various reaches of the river that could be related to bank configuration, depth, turbulence, velocity or other physical features. Detailed tracking could provide information on fish behaviour at obstructions or points of difficult passage and on the ability or tendency for the fish to cross from bank to bank. Figure 1 outlines the general study area.

2.1 METHODS AND EQUIPMENT

2.1.1 Capture and Tagging of Fish

Sockeye intended for radio tagging were captured at two locations, Lytton and Saddle Rock (Figure 2), using a dip net hung with approximately 5 cm stretch nylon mesh. At Lytton, approximately 0.8 km upstream of the Fraser-Thompson confluence at CN MP 97 (referring to CN mileposts in the Yale and Ashcroft Subdivisions as marked in Figure 2), fish were captured on the left bank of the Thompson River at a location where they were forced to migrate through relatively high velocities as a result of a rock obstacle on the bank. Immediately downstream of Saddle Rock (CN MP 22) on the right bank of the Fraser River, fish were captured in two back eddy pools.

Upon capture, each fish was immediately removed from the dip net using a wool mitt. The fish was then placed on a tagging board, sexed, measured for length to the nearest centimetre, and tagged with a numbered red plastic Petersen disc tag below the dorsal fin. The radio transmitter was then inserted orally into the fish's gut using a 20 cm glass tube. The fish was immediately released into the river and the radio signal was monitored to verify the frequency setting, signal strength and pulse rate.

Steelhead were captured by angling at the Fraser-Thompson confluence. Three of the steelhead caught were fitted with radio transmitters.

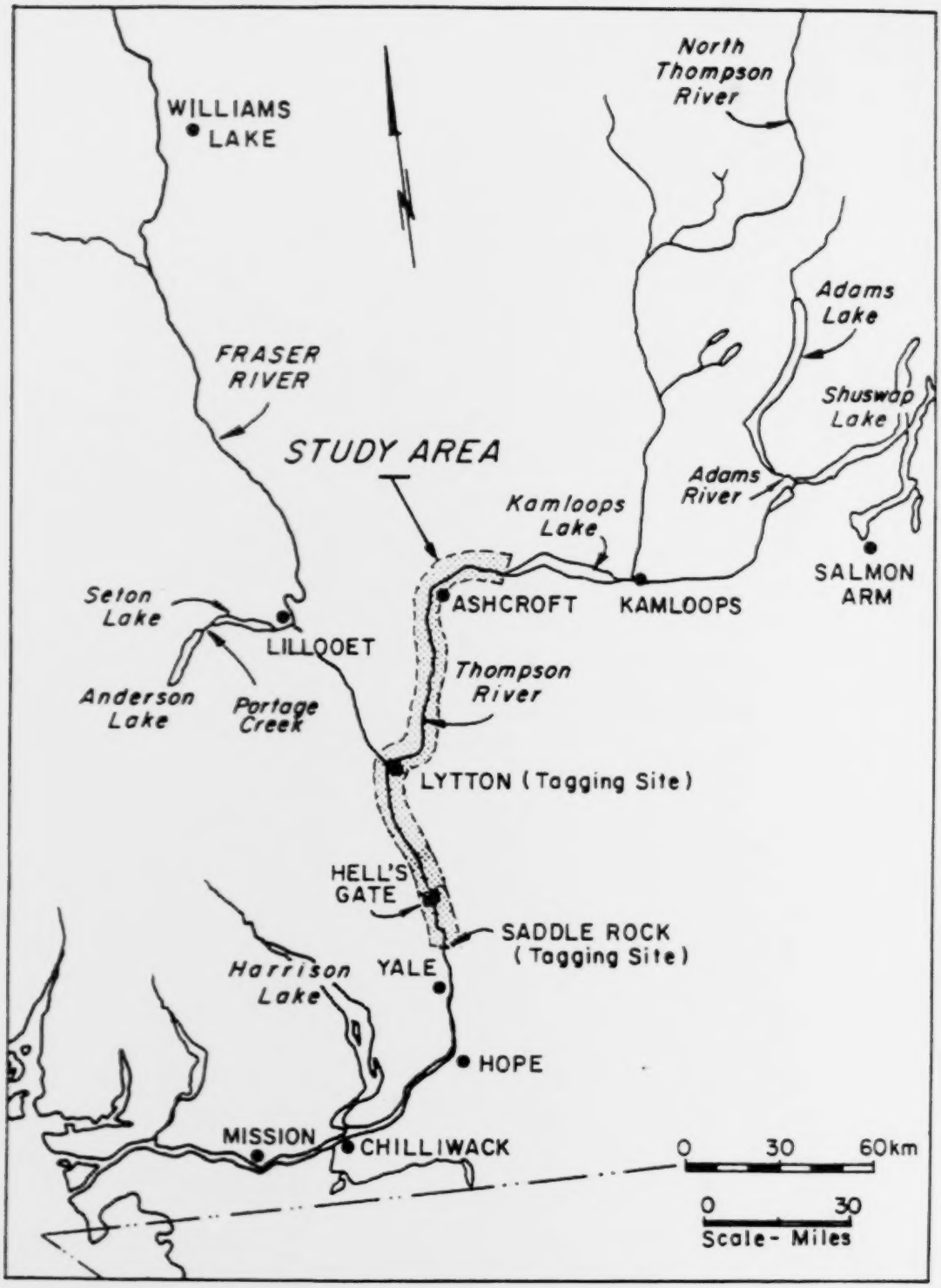


FIGURE 1. Location of Study Area

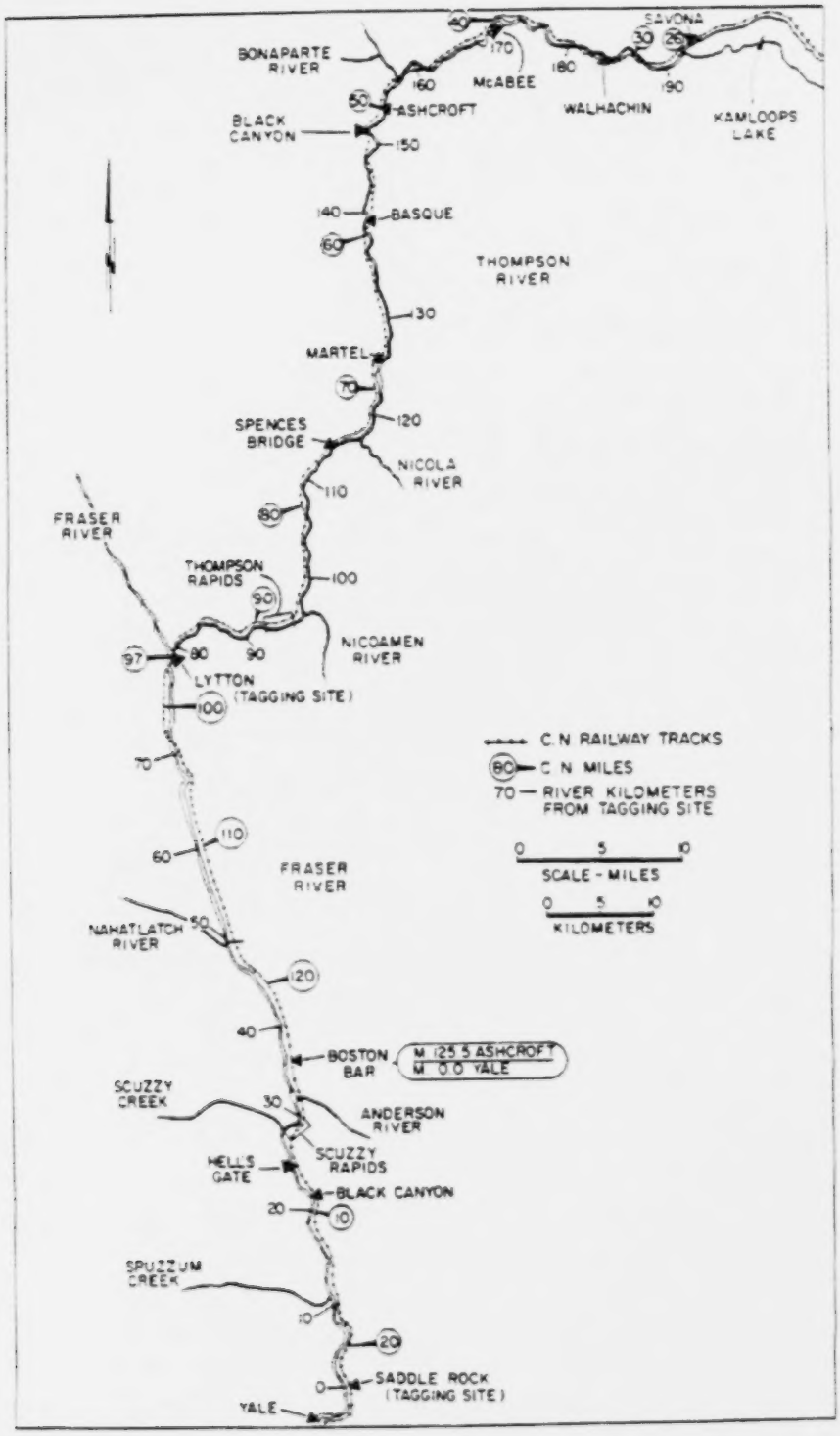


Figure 2 CN Railway Mileage in the Study Area

2.1.2 Radiotelemetry Equipment

Radio Transmitters: Radio transmitter modules obtained from AVM Instrument Co. of California were inserted in 34 sockeye, each consisting of an SM-1 transmitter, tuned loop antenna and a power source, all potted in dental acrylic and waterproofed with beeswax. The finished module was approximately 3.5 cm long, 1.5 cm wide and 1.2 cm deep. The manufacturer's specifications indicate a total module weight of 4.5 g prior to application of the beeswax.

The power source utilized was an Hg-675 battery which provided a transmission life of approximately 8-10 weeks at a current drain of .056-.082 mA and a pulse rate of 52-96 pulses per minute. Each transmitter operated at a designated frequency within the 49.3-49.6 MHz range. Signal drift of up to $\pm$ 3-4 kHz was common. Some fluctuation also occurred in the pulse rate which typically varied as much as $\pm$ 5 pulses per minute. Signal range varied with the location of the fish in the water column, topography, and elevation of the receiver. Typical tracking ranges were approximately 300 m when tracking on foot with an M-Yagi antenna, 600-800 m from a vehicle, and 1 km from an aircraft.

Transmitters were adapted for insertion into steelhead. These were standard AVM 20 g transmitting modules equipped with magnetic on-off switches and capable of transmitting in the 50 MHz range.

Radio Receivers: Five LA-12 receivers used during this project were single channel receivers which could be manually tuned to receive any signal within the 49.3-49.6 MHz range. Three of those units were equipped with sweep options which provided automatic scanning of any one of twelve 25 kHz channels. A sixth LA-12 receiver which operated on a higher frequency was used to track the tagged steelhead. The receivers were powered with nickel-cadmium rechargeable batteries. Monaural or converted stereo headphones were generally used to facilitate tracking.

Receiving Antennae: Portable M-Yagi or miniature loop antennae were used when tracking on foot or motorcycle. Tracking was also conducted using vehicles equipped with 1.52 m omnidirectional whip antennae. A similar whip antenna mounted on the step of a Cessna 172, was

utilized for tracking from the air. Occasionally, a 12 m trailing dipole antenna was used in conjunction with the aircraft.

2.1.3 Tracking

Aerial tracking was conducted daily from a Cessna 172 along sections of the Thompson and Fraser rivers from Kamloops Lake downstream to Yale (Figure 2). The flight generally began at about 0800 PST from a small grass airstrip near Ashcroft. Effort was directed to areas where tagged fish were expected on the basis of previous locations and migration rates. The plane was flown at an elevation of 150-250 m above the river and at a velocity of 60-80 knots. Seven tagged fish could be scanned at any time by manually adjusting the radio receiver settings. After receiving a signal, the location of the fish could be recorded within about 0.8 km. CN mileposts (CN MP) were used to describe fish locations on 1:50,000 topographic maps. Distance travelled was measured in river kilometers originating from Saddle Rock (River kilometer 0), the downstream boundary of the study area. Migration rates were subsequently calculated in terms of kilometers per hour.

2.2 RESULTS

Between September 28 and October 10, 1982, a total of 34 sockeye were radio tagged and monitored along the Fraser and Thompson rivers. Of the 34 sockeye, 13 had been caught and released at Lytton on the Thompson River and 21 at Saddle Rock on the Fraser River (Figure 2). Three of the sockeye caught at Saddle Rock were later determined to be Portage Creek sockeye which continued to migrate upstream in the Fraser River to Seton Lake near Lillooet (Figure 1).

Each radio tagged fish was successfully located approximately 90% of the time, during daily aerial tracking flights. The average migration rate of the radio tagged sockeye from the time of release until the final observation was determined to be 0.85 km/hr or 20 km/day (Table 1). Refer to Appendix I for the raw data on individual migration rates and tracking records.

2.2.1 Effect of Tagging

The average rate of migration for most of the fish was observed to be lower during the first 24-48 hr period following tagging

Table 1 Effects of Tagging on Migration Rates of Radio Tagged Sockeye

Fish Tagging Location	Fish No.	Migration Rate from Release to First Location km/hr	Migration Rate from Release to Final Location km/hr	Estimated Delay at Tagging Site
Lytton	1	0.67	1.13	4
	2	0.68	1.48	4
	3	0.64	1.22	5
	4	0.60	1.06	6
	5	0.67	1.29	4
	6	0.31	0.92	10
	7	0.38	0.33	9
	8	0.38	1.00	9
	9	0.19	1.02	12
	10	0	0.57	77
	16 [1]	0	0.38	40
	17	0	0.37	135
	18	0.07	0.69	41
	Mean	0.35	0.88	27
Saddle Rock	11	0.66	0.80	4
	12	0.50	0.64	8
	13	0.41	0.87	10
	14	0.98	1.18	0
	15	0.42	0.90	10
	19	0.71	0.94	4
	20	0.64	0.80	5
	21 [2]	0.37	0.67	12
	22	0.74	0.80	3
	23	0.98	0.76	0
	24	0.90	1.02	0
	25	0	0.82	22
	26	0.40	1.04	11
	27	0.50	-	18
	28	0	0.46	25
	29	0	0.90	19
	30 [2]	0.84	0.68	0
	31 [2]	0.52	0.63	16
	32	0.14	0.68	18
	33	0	0.98	22
	34	0.46	0.99	19
	Mean	0.48	0.83	11
Overall Mean		0.43	0.85	17

[1] Assumed dead at CN MP 52
[2] Portage Creek sockeye

than for the overall observed migration. The average rate of travel from release at the tagging site to the first upstream tracking location (a 1-2 day interval) was 0.43 km/hr, about half the overall rate of 0.85 km/hr (Table 1).

In many cases, this reduced initial rate was observed to be a result of delay in fish movement at or near the tagging site. The delay at the tagging site was estimated by calculating the time required for each fish to swim from the tagging site to the first upstream location based on the overall average migration rate (0.85 km/hr) and subtracting this from the actual time taken (Appendix I). This calculation indicated that all but four fish were delayed to some extent following tagging (Table 1). Most delays ranged between 3 and 25 hours, however, four fish released at Lytton exhibited protracted delays of between 40 and 135 hours. The overall average delay after tagging was 17 hr. However, the average delay at the tagging site was more than double for fish tagged at Lytton (27 hr) as compared with fish tagged at Saddle Rock (11 hr) due to the four long delayed fish.

2.2.2 Migration Rates

Migration rates generally increased as the fish proceeded upstream, likely in relation to the hydraulics of the various river reaches. These have been evaluated on the basis of reach changes (Table 2, Figure 3).

Fish tagged at Saddle Rock generally demonstrated a steady increase in migration rate from an initial rate of 0.48 km/hr immediately following tagging to 1.35 km/hr at the upper end (Table 2, Figure 3). In the reach from Black Canyon (CN MP 9.5, Yale Sub) to above Scuzzy Rapids (CN MP 5, Yale Sub) which includes Hell's Gate, the average rate of travel was 0.71 km/hr. There was an increase in the migration rate from the first location despite some observed delay in this section of the river where several rapids and narrow canyons exist. A further increase in migration rate occurred in the upper section of the Fraser River from Scuzzy Rapids to Lytton, where there are no major rapids or constrictions. The migration rate in this reach averaged 1.05 km/hr.

There was no indication of a markedly reduced migration rate or apparent delay at the Fraser-Thompson confluence. Migration rates over a suitably short section of river encompassing the confluence are available for only six fish (Table 2). Two fish increased their migration speed, two maintained a constant rate and two decreased their speed, for an average rate of 0.97

Table 2 Summary of Sockeye Migration Rates in the Fraser and Thompson rivers between Saddle Rock and Kamloops Lake

Fish Tagging Location	Fish No.	Below Black Canyon to Above Scuzzy Rapids km/hr	Above Scuzzy Rapids to Lytton km/hr	Fraser/ Thompson Confluence km/hr	Thompson Rapids to Ashcroft km/hr	Ashcroft to Kamloops Lake km/hr
Lytton	1				1.58	1.92
	2				1.82	1.98
	3				1.43	1.53
	4				1.69	1.78
	5				1.43	1.79
	6				0.87	1.42
	7				-	-
	8				1.30	1.43
	9				0.97	1.56
	10				1.17	1.51
	16				0.76	-
	17				0.89	1.38
	18				1.19	1.74
	Mean				1.26	1.64
Saddle Rock	11	0.53	1.08	0.61	0.93	1.32
	12	0.43	0.97	0.97	0.79	1.05
	13	0.60	0.97	-	1.38	2.25
	14	0.61	1.48	-	1.48	-
	15	0.84	0.68	1.08	1.16	1.35
	19	0.55	1.06	-	1.26	1.72
	20	0.69	0.77	-	1.21	1.16
	21 [1]	0.35	1.14	-	-	-
	22	0.74	0.76	0.87	0.90	1.35
	23	0.61	-	-	0.89	1.06
	24	0.47	1.27	-	1.16	1.42
	25	0.68	0.77	-	1.29	1.22
	26	0.95	1.17	-	1.16	1.90
	27	-	-	-	-	-
	28	0.37	1.03	1.00	0.26	-
	29	1.19	1.05	-	1.16	-
	30 [1]	0.68	0.85	-	-	-
	31 [1]	0.72	-	-	-	-
	32	0.71	1.22	1.22	-	-
	33	1.19	1.19	-	1.34	1.38
	34	1.22	1.29	-	0.98	1.45
	Mean	0.71	1.05	0.97	1.08	1.35
Overall Mean		0.71	1.05	0.97	1.16	1.53

1 Portage Creek Sockeye

km/hr, only slightly slower compared with the previous section above Scuzzy Rapids to Lytton. Many fish demonstrated reduced migration rates through the Thompson Rapids. This point of delay located a short distance upstream of Lytton will be further discussed in the next section.

The reach upstream of Thompson Rapids (CN MP 88, Ashcroft Sub) to Ashcroft (CN MP 49, Ashcroft Sub.) is characterized by steep sided canyons alternating with open valleys, and has no major rapids at the water levels occurring during the study. The migration rate in this reach increased to 1.16 km/hr (Table 2). Upstream of Ashcroft to Kamloops Lake, the Thompson River meanders through a wide valley. No canyons or rapids occur and the water velocity is less than that in downstream reaches. The migration rate in this section increased to 1.53 km/hr (Table 2).

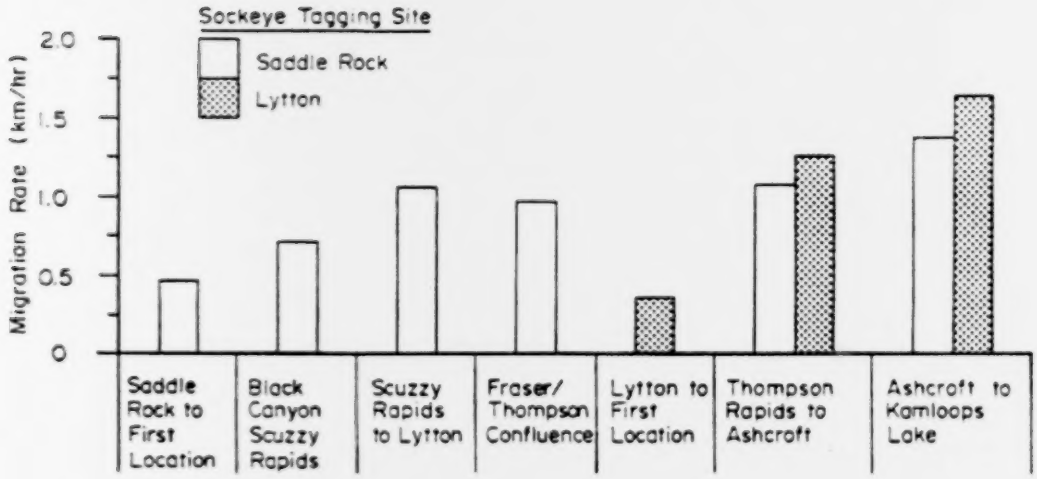


Figure 3 Variation in Migration Rates of Radio Tagged Sockeye in the Fraser and Thompson Rivers

2.2.3 Points of Delay

Two sections were identified as points of delay from relatively continuous migration. One occurred in the Fraser River from Black Canyon (CN MP 9.5, Yale Sub) to Scuzzy Rapids (CN MP 5, Yale Sub) and the other on the Thompson River at the Thompson Rapids (CN MP 88 - 89, Ashcroft Sub). Figures 4 and 5 show individual trackings illustrating points of delay.

Black Canyon to Scuzzy Rapids: There were incidences of successive radiotelemetry observations of the same fish at the same location for periods up to 49 hrs, which indicated that the fish were not moving upstream (Table 3). In addition, migration rates of many fish decreased in this section from the rates observed during the previous interval. The delay implied by the reduced rate in this section was estimated by calculating the time which would have been required to migrate through the section at the rate recorded immediately upstream and subtracting this time from the observed time. In instances where successive sightings were made at the same location, the point of delay could be determined. However, in other cases only a general location was indicated because a series of successive sightings was not taken throughout the section of the river where a delay occurred, and the fish were therefore not spotted immediately below any obstruction.

Although there were indicators of delay based on repeated sightings at both Black Canyon and Scuzzy Rapids, similar observations were not made at Hell's Gate (see Figure 2). Therefore, some of the delays attributed to the general area could have occurred at Hell's Gate.

Thompson Rapids: Large numbers of the Adams River sockeye were delayed at several locations along the Thompson River Rapids. The delay was evident in the radiotelemetry tracking observations as plotted in Figures 4 and 5, by the steep slopes of the migration rate curves at the Thompson Rapids.

Delay in migration at Thompson Rapids was determined by the observed delay (successive radiotelemetry observations at this point) or by comparison of the rate that would have been expected in this reach based on the rate measured in the adjacent section of river. The average period of delay in Thompson Rapids was 9.0 hrs based on 30 fish (Table 3). Of the 30 fish, 13 demonstrated no measurable delay and the remaining 17 were delayed from 4 to 40 hrs.

FIGURE 4
Composite of all Sockeye Tagged at Saddle Rock

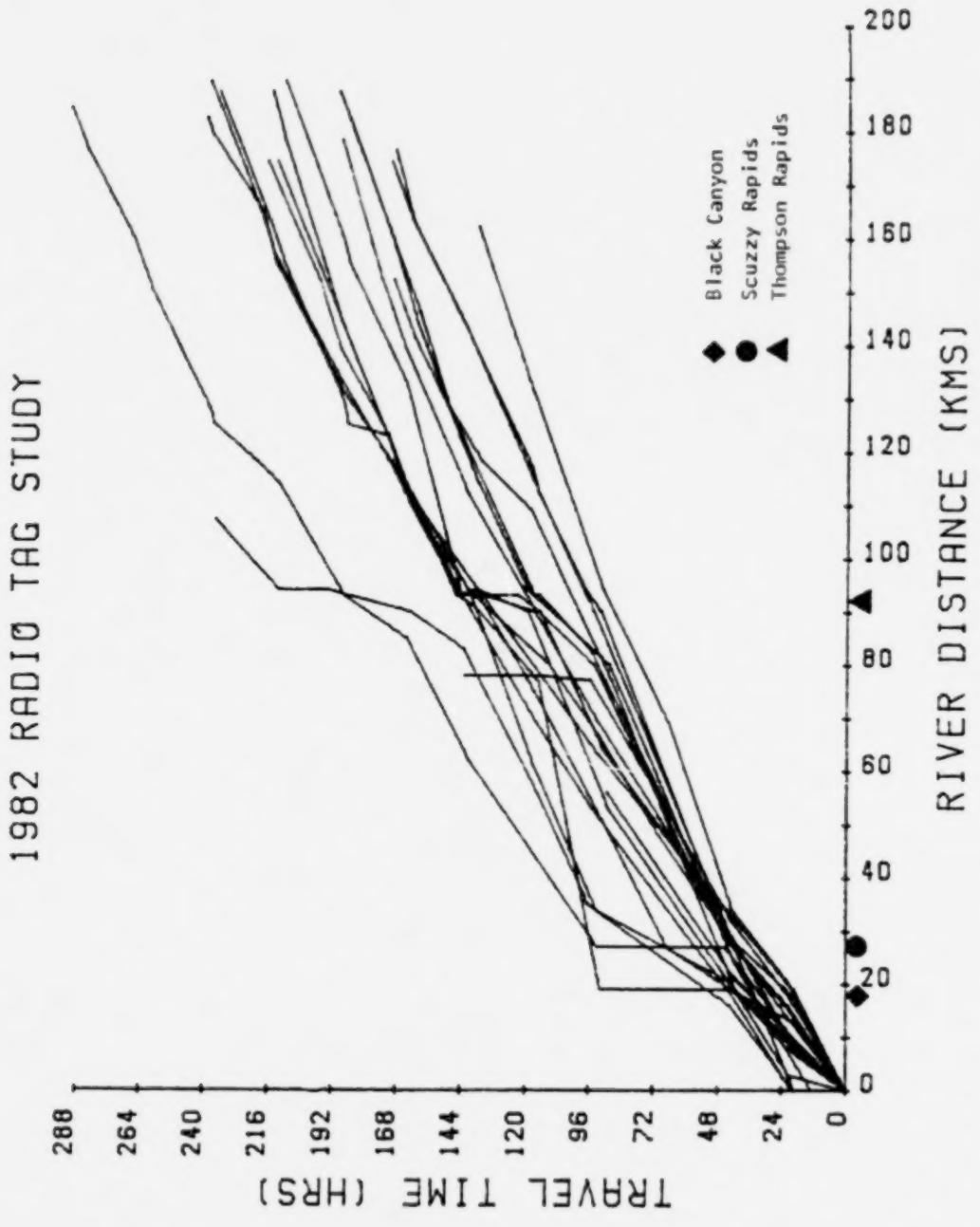


FIGURE 5
Composite of all Sockeye Tagged at Lytton

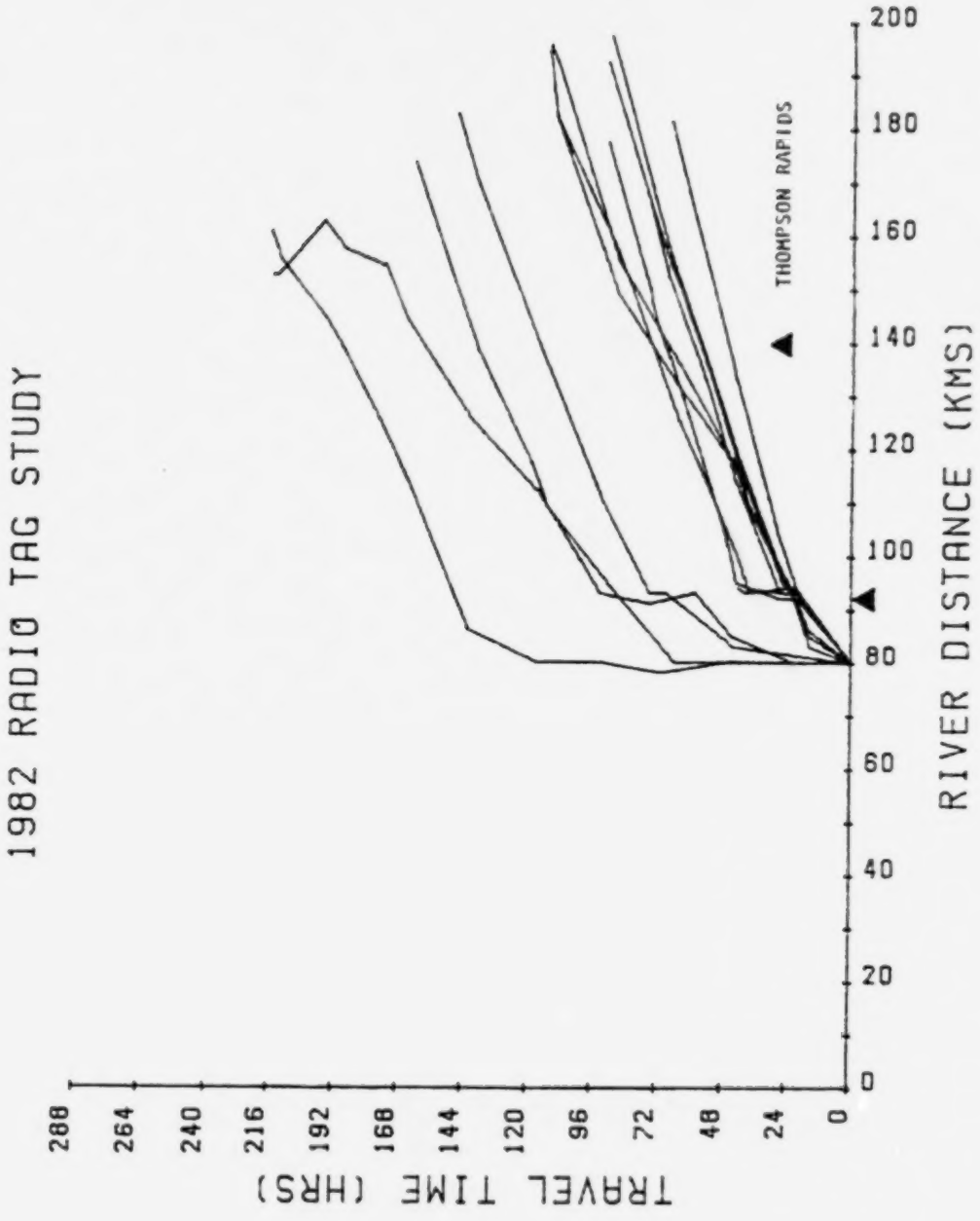


Table 3 Points of Delay Identified in the Fraser and Thompson River for Radio Tagged Sockeye

Tagging Location	Fish No.	Location of Delay (River km[1])			Estimated Period of Delay (hours)	
		Black Canyon	Scuzzy Rapids	Thompson Rapids	Black Canyon to Scuzzy Rapids	Thompson Rapids
Lytton	1			94		7
	2			-		0
	3			93		4
	4			93		20
	5			93		6
	6			-		0
	7			94		20
	8			93		18
	9			-		0
	10			-		0
	16			93		40
	17			-		0
	18			93		6
Saddle Rock	11	19	-	93	14	5
	12	-	27	93	49	15
	13	-	27	94	16	6
	14	19	34	-	15	0
	15	-	-	93	0	26
	19	16	29	-	11	0
	20	-	-	-	0	0
	21 [2]	21	34	-	37	-
	22	16	29	94	9	21
	23	20	63	-	7	0
	24	18	29	-	15	0
	25	19	53	-	7	0
	26	-	-	-	0	0
	28	16	35	94	35	34
	29	-	-	93	0	11
	30 [2]	16	32	-	5	-
	32	19	53	94	20	14
	33			94		18
	34			-		0
	Mean				18	9

1 Refer to Figure 2 for River km locations
2 Portage Creek Sockeye

2.2.4 Day versus Night Migration

On many occasions, radio tagged fish were located more than once a day either during two flights or once while air tracking and once while ground tracking. This provided the opportunity to compare the rate of migration during two consecutive intervals, one comprising entirely daylight hours (minimum 4 hour period) and one comprising an average of five daylight hours and approximately 12 hours of darkness. Based on observations above Thompson Rapids (Appendix I), the average migration rates during daylight and darkness were 1.40 and 1.07 km/hr, respectively (Table 4).

Since the latter interval included an average of five hours of daylight, the actual rate of migration during darkness was likely less than 1.07 km/hr. This evaluation, however, is an oversimplification of the matter and is presented here to show the general trend based on the observations of the current study.

2.2.5 Comparison of Migration Rates of Males and Females

Little difference was observed between male and female migration rates through the various river reaches (Figures 6-9). The same points of delay were observed for both sexes. The overall migration rate of radio tagged males was 0.84 km/hr (N=14) and of radio tagged females was 0.90 km/hr (N=18).

2.2.6 Steelhead

Three steelhead were radio tagged and released just upstream of the Fraser/Thompson confluence at Lytton (CN MP 97) between October 9 and 10, 1982 (Table 5). Two of the steelhead (fish #35 and 37) were located only once after tagging. Extensive searches along the Fraser River 40 km above and below Lytton, and along the Thompson River as far as the to Nicola River failed to relocate these fish. The remaining steelhead (fish #36) was located daily after tagging until termination of the tracking program. This fish delayed at the release site for 3 days and then moved slowly (0.5 km/day) upstream to river km 84 (CN MP 94.0) by October 17. No further tracking was conducted.

Table 4 Comparison of Consecutive Day and Overnight Migration Rates observed in the Thomspon River above Thompson Rapids

Fish No.	Day Migration Rates		Night Migration Rates	
	km/hr	Number of Observations	km/hr	Number of Observations
1	1.82	2	1.42	1
3	1.54	2	1.53	2
4	1.71	1	1.73	1
5	1.73	1	1.81	1
6	1.27	1	0.72	1
	1.50	1	1.40	1
9	1.43	1	0.92	1
10	1.43	3	1.27	2
11	1.29	1	0.14	1
	1.48	1	1.27	1
12	0.50	1	0.43	1
	1.36	2	0.94	1
13	1.76	3	1.40	2
16	0.97	2	0.20	1
17	1.13	3	0.82	2
19	1.48	1	1.73	1
20	1.53	2	0.90	1
22	0.97	1	0.82	2
	1.60	1	1.28	1
23	0.97	1	0.73	1
	1.89	1	0.76	1
24	1.38	1	0.99	1
29	1.41	1	1.04	1
33	1.50	2	1.36	2
Mean	1.40 km/hr	Day	1.07 km/hr	Night

FIGURE 5
Male Sockeye Tagged at Lytton

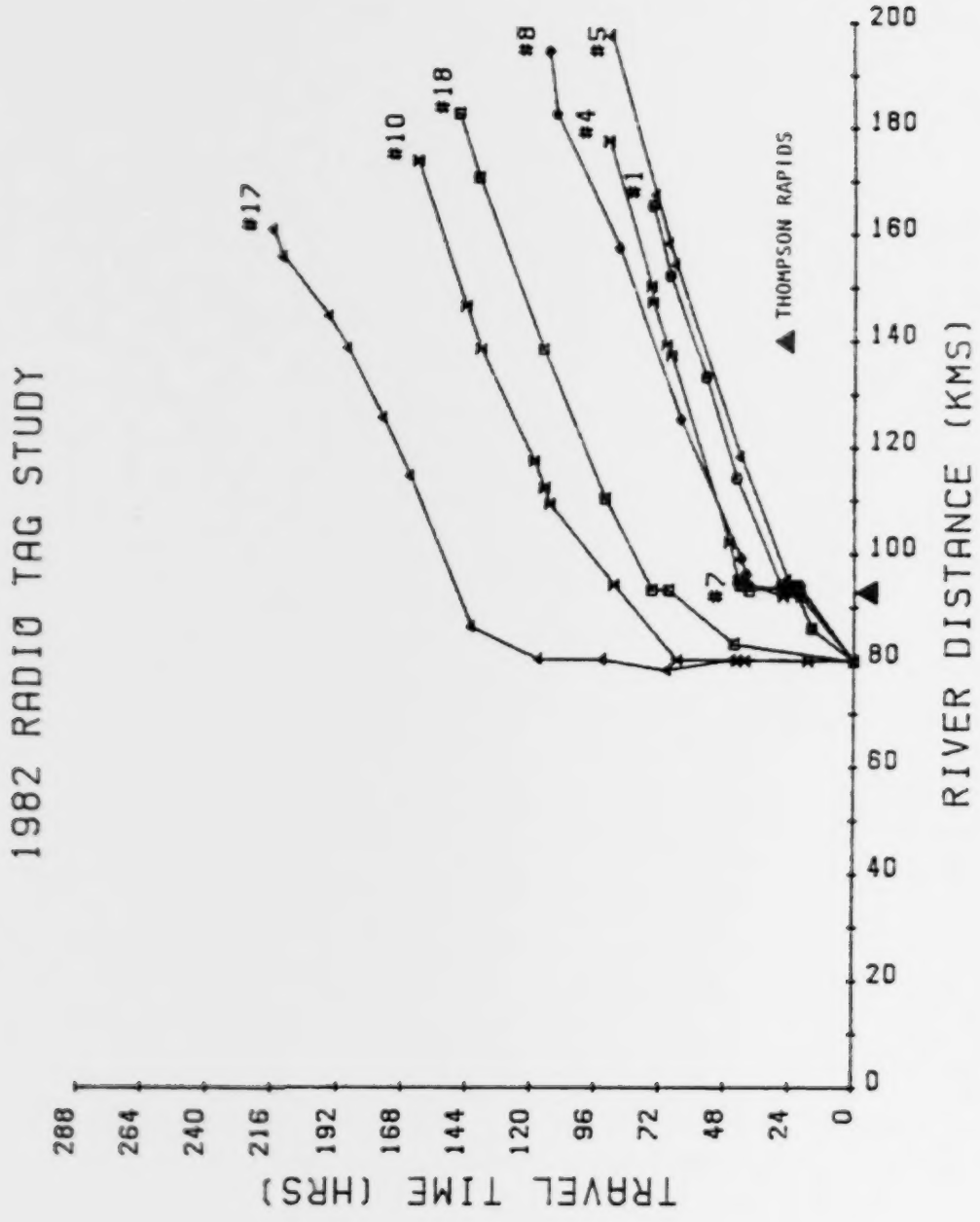


FIGURE 7
Female Sockeye Tagged at Lytton

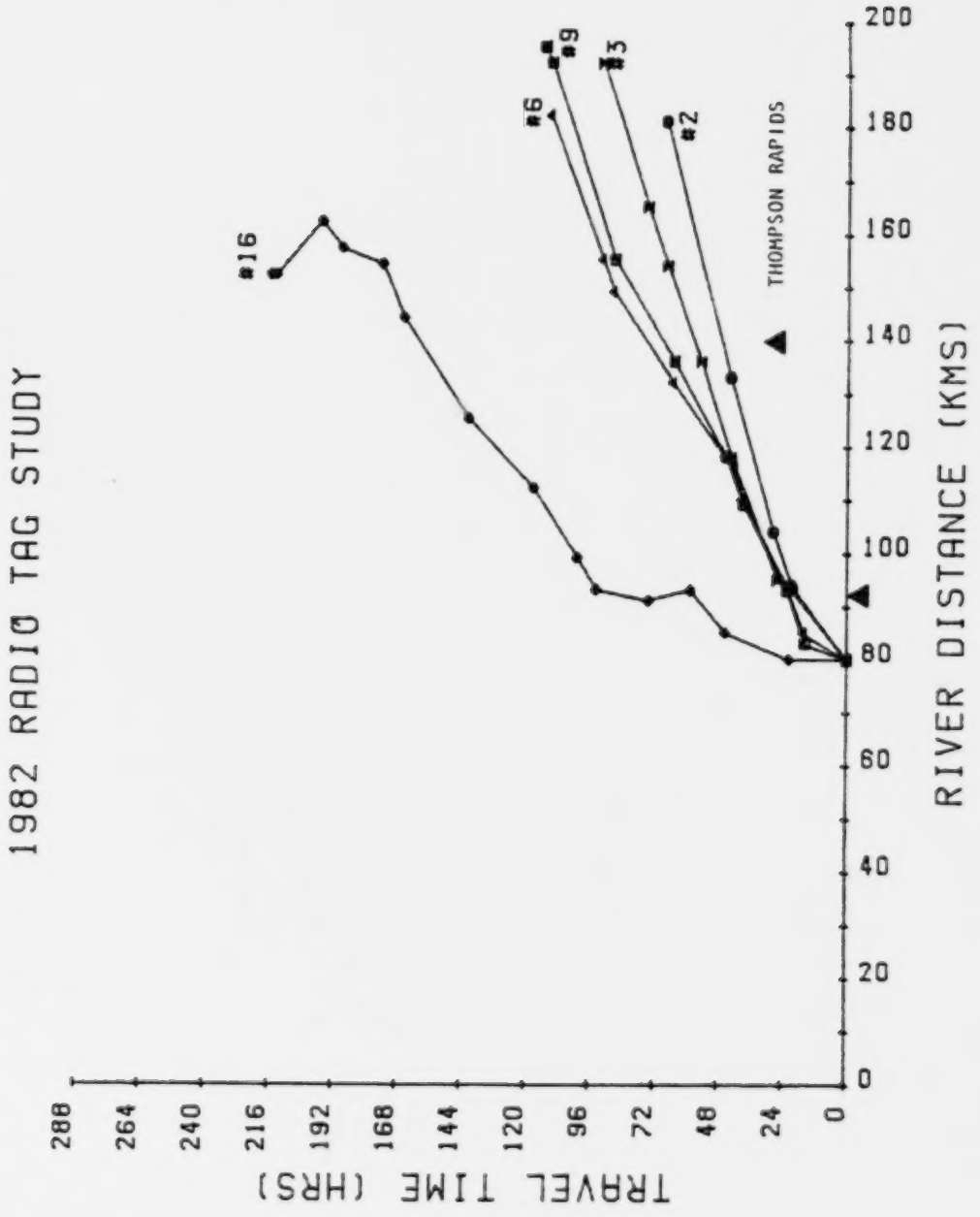


FIGURE 8
Male Sockeye Tagged at Saddle Rock

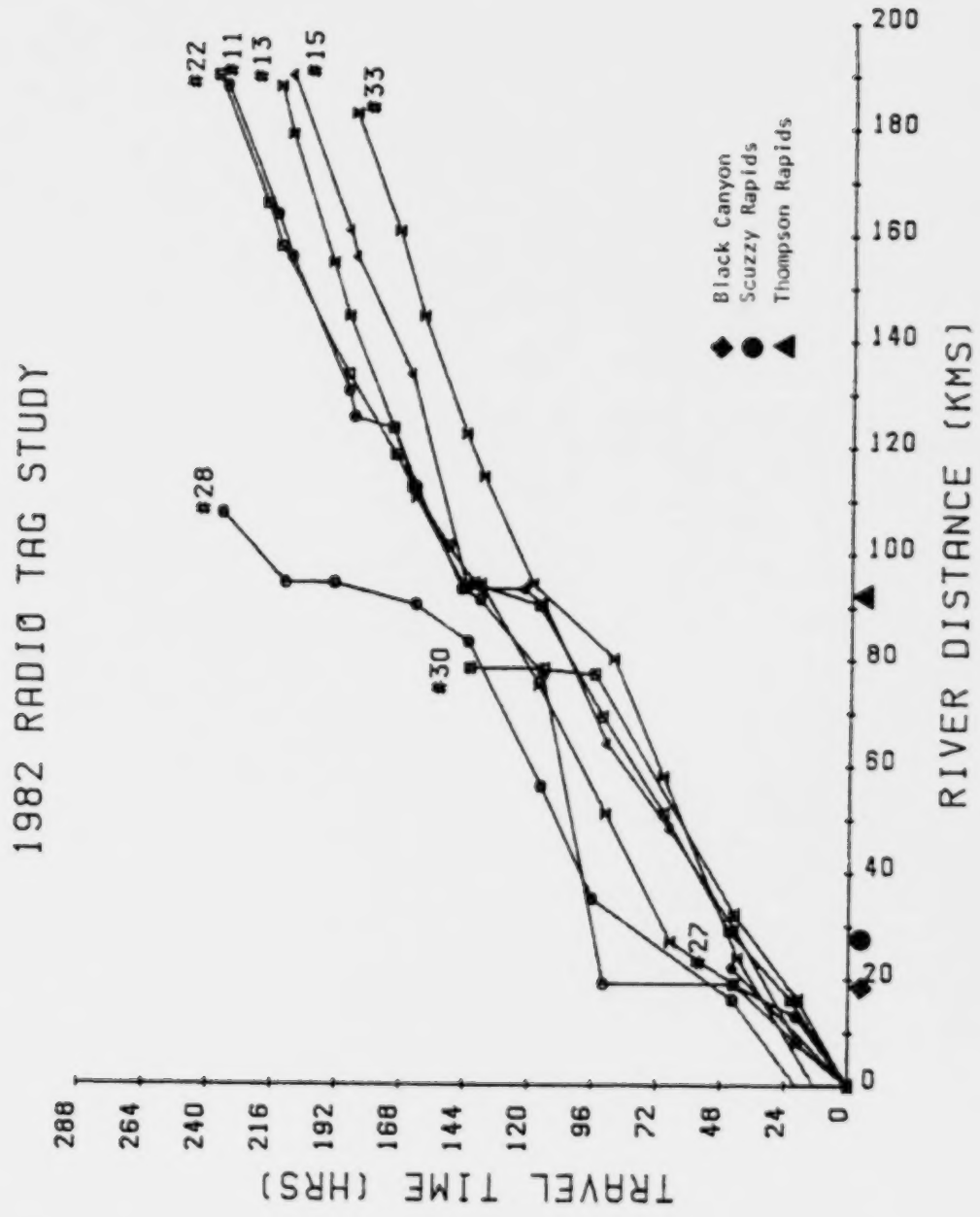


FIGURE 9
Female Sockeye Tagged at Saddle Rock

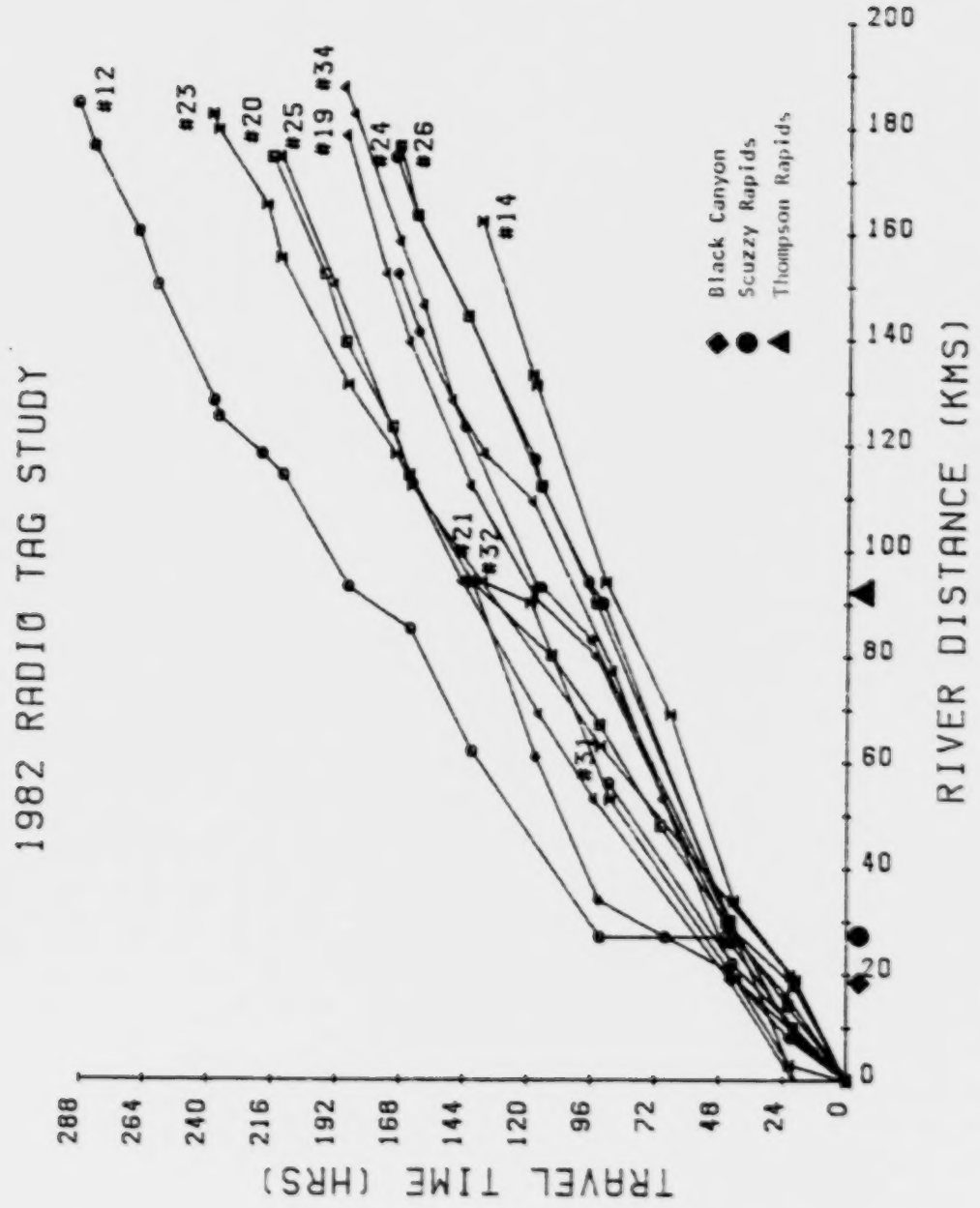


Table 5 Radio Tagged Steelhead Released at Lytton (CN MP 97).

Fish #	Sex	Estimated Weight (kg)	Date of Release	Period of Tracking	Location at Final sighting (CN MP)
35	F	6.0	Oct. 9	Oct. 10	99
36	F	7.7	Oct. 9	Oct. 10-17	94
37	M	8.0	Oct. 10	Oct. 11	98

2.3 DISCUSSION

The Adams River and Shuswap Lake sockeye radio tagged during this study were obtained as the peak portion of the run passed Lytton and Saddle Rock. Consequently, the behaviour observed should be representative of the population as compared to the possible biased behaviour of early or late migrating fish. However, the capture technique (dip net) could have selected for fish which tend to migrate along the margins of the river or fish prone to delay either due to weakness or early timing, such as the fish caught in a pool immediately downstream of Saddle Rock. The latter possibility for selection of a particular type of fish is demonstrated by the disproportionately large catch of three Portage Creek sockeye relative to 18 Adams River fish caught at the Saddle Rock site. The size of the Portage Creek sockeye run was less than 1% of the Adams River run. Portage Creek sockeye have been observed to delay at the tailrace of Seton Creek Generating Station (Fretwell, 1982). Similar delay behaviour at Saddle Rock likely resulted in increased probability of capture at the tagging site. Therefore, the Adams River sockeye captured at Saddle Rock may also represent a portion of the run prone to slower migration.

2.3.1 Migration Rates

The average migration rate of 0.85 km/hr or 20 km/day determined in current study (Table 1) is one quarter slower than the rate of 27 km/day reported by Killick (1955) for the migration of Adams River sockeye from Hell's Gate to the spawning grounds. However, the latter figure does not include the 24 km section between Saddle Rock and Hell's Gate where the migration was slowest. The 27 km/day rate was also likely inflated relative to the results of the current study because a

substantial portion of that rate included migration measurements taken in relatively low velocity water through Kamloops and Little Shuswap lakes, and the slow moving South Thompson River. The migration rate of the 1982 radio tagged fish increased dramatically in the Thompson River above Ashcroft to 1.53 km/hr or 37 km/day (Table 2). This rate of migration was likely maintained or increased from the outlet of Kamloops Lake to the spawning grounds in the Adams River. A similar increase in the rate upstream of Hell's Gate was observed by Killick (1955) and others (Anonymous 1965). The observed average migration rate of the radio tagged fish would also be increased by 1.5 km/day to 22.5 km/day by adjusting for the initial average 17 hr delay observed to result from tagging.

The Adams River sockeye migration rate for the current study compares favourably with the rate cited by Killick (1955) when the above factors are considered. Therefore, the effects of tagging and the presence of the radio transmitter appeared to have had little effect upon the migration of the fish beyond the initial average 17 hr delay after tagging. Also, the fish captured for tagging were probably representative of the run because the 1982 rate was comparable to past years based on IPSFC records. A slower migration rate might have been expected if the fish captured were primarily the weaker fish swimming along the margins such as fish #16 which was assumed to have died during migration near Ashcroft. However, this was an exception.

2.3.2 Diel Migration Pattern

The diel pattern of salmonid migration behaviour reported in the literature is highly variable and may be related to a number of factors including seasonal timing of the run (Gilhousen, 1980), stream discharge or light (Lister, 1981), stage of the run, and the species. In some instances, no consistent diel pattern has been observed (Ellis, 1962).

The results of the present study indicate some reduction in migration activity occurred at night by comparing the estimated average night rate of 1.07 km/hr with the daylight rate of 1.42 km/hr (Table 4).

Many observations of predominantly daytime migration behaviour have been made at obstructions such as fishways and rapids (Ward, 1959). Diel migration continuity may be interrupted at such obstructions with fish unwilling to pass under certain light conditions. During the present study there was an

obvious tendency for fish to negotiate Thompson Rapids during daylight hours. Only one out of 26 fish appeared to pass through Thompson Rapids during hours of darkness.

3.0 DETAILED TRACKING

3.1 METHODS

Individual fish were tracked by foot or motorcycle after being initially located from the aircraft or highway vehicle. The location of individual fish as determined from the air was transmitted by radio to observers on the ground. The observers were then able to locate the fish more accurately for detailed tracking. The initial ground location was determined from a vehicle using a whip antenna or from a motorcycle using a portable M-Yagi or miniature loop antenna. The experienced observer was then able to follow the migrating fish and to determine some behavioural characteristics such as bank preference, bank switching and migration speed in various river reaches. Areas of delay, such as the Thompson Rapids, could also be identified.

3.2 RESULTS

Sections of the Thompson River in which most of the detailed tracking occurred included:

Section 1 CN MP 78-72 (Spences Bridge)
Section 2 CN MP 55-50 (Upper Black Canyon)
Section 3 CN MP 50-44 (Ashcroft)
Section 4 CN MP 44-39 (McAbee)
Section 5 CN MP 39-34 (Anglesey)
Section 6 CN MP 34-30 (Walhachin)

All CN MP locations indicated are within the Ashcroft Subdivision. Figure 10 provides an overview of the section locations. Tracking of individual fish was undertaken along other sections of the river as well, but have not been included on the following figures because they were isolated cases. Refer to Appendix II for the complete detailed tracking results.

Initially, the detailed tracking was to take place in predetermined sections of the river based on areas most likely to be affected by the proposed encroachment from CN's Twin Tracking Program, known to be difficult for migrating salmonids, and typical of many other river sections. This plan became

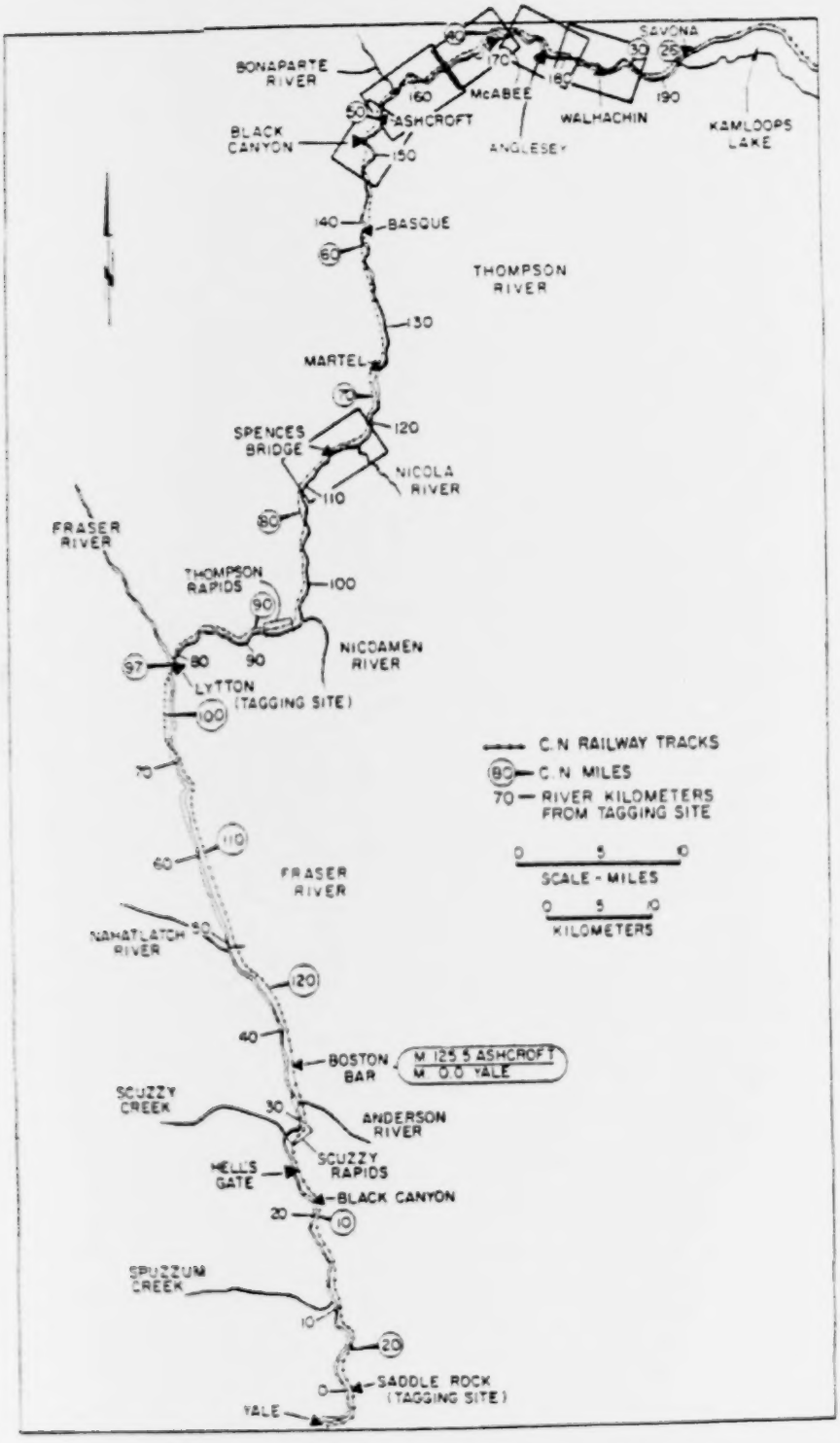


Figure 10. Overview of Detailed Tracking Sections

inoperative, however, because fish location could not be predetermined accurately and because migration also took place at night when tracking was not feasible. Therefore, where possible the fish were tracked through areas previously selected for study while other fish were tracked where they happened to be located during early morning overflights.

The accuracy of detailed tracking varied due to the fluctuation in signal strength which depended on the depth at which the fish was swimming. In addition, difficulty was experienced in determining the precise direction of the signal. These factors made it difficult to determine if the fish was in the middle of the channel or on the opposite bank, but with practice the uncertainty was minimized. In contrast, accuracy of tracking fish swimming along the same shoreline as the observer was verified on a number of occasions where the fish (identified by the Peterson disc) were spotted by the observer as they migrated upstream (e.g. fish #9, 12, 15, 16 and 33). Accuracy was increased by reducing the size of the receiving antenna as the signal strength increased (i.e. a pocket knife held upright on the antenna connection in the receiver was sufficient to locate fish within a distance of 30 m).

Some patterns to fish migration emerged from tracking information in some of the river sections monitored. However, in most cases definite pathways could not be ascertained. A discussion of the detailed tracking results in each of the sections is as follows.

3.2.1 Section 1 CN MP 78-72 (Spences Bridge)

This section of the Thompson River includes Spences Bridge (CN MP 74.5), the confluence of the Nicola River (CN MP 73.2), and two highway bridge crossings (CN MP 74.6 and 75.1). The Thompson River at this location follows a slight meandering pattern with point and mid-channel bars associated with the bends. The CNR follows the right bank, which is subject to active river erosion throughout most of this section.

Two areas of encroachment are proposed between CN MP 72.9 to 73.5 and 75.5 to 75.6. The former is characterized by an oversteepened rip-rap bank with bedrock outcrops and is situated directly across from the mouth of the Nicola River. There is an important steelhead fishing area along both banks of the Thompson River in the immediate area of the Nicola River (Reid, Crowther and Partners Ltd. 1982). The latter encroachment is located on an outside bend which is also in an oversteepened condition with existing rock fill. No fish were tracked in the immediate area of this proposed encroachment.

A total of seven fish (#6, 9, 10, 12, 16, 17 and 33) were tracked through this area (Figure 11). Detailed tracking from CN MP 75 to 73.5 revealed that fish swam along both sides of the river, however, a minor preference was shown for the right bank. Fish counts at CN MP 75.1 on October 7 and 8 indicated that 82% (235 vs. 52) were on the right side (Table 6). Two of the three radio tagged fish tracked through this area were also located on the right bank.

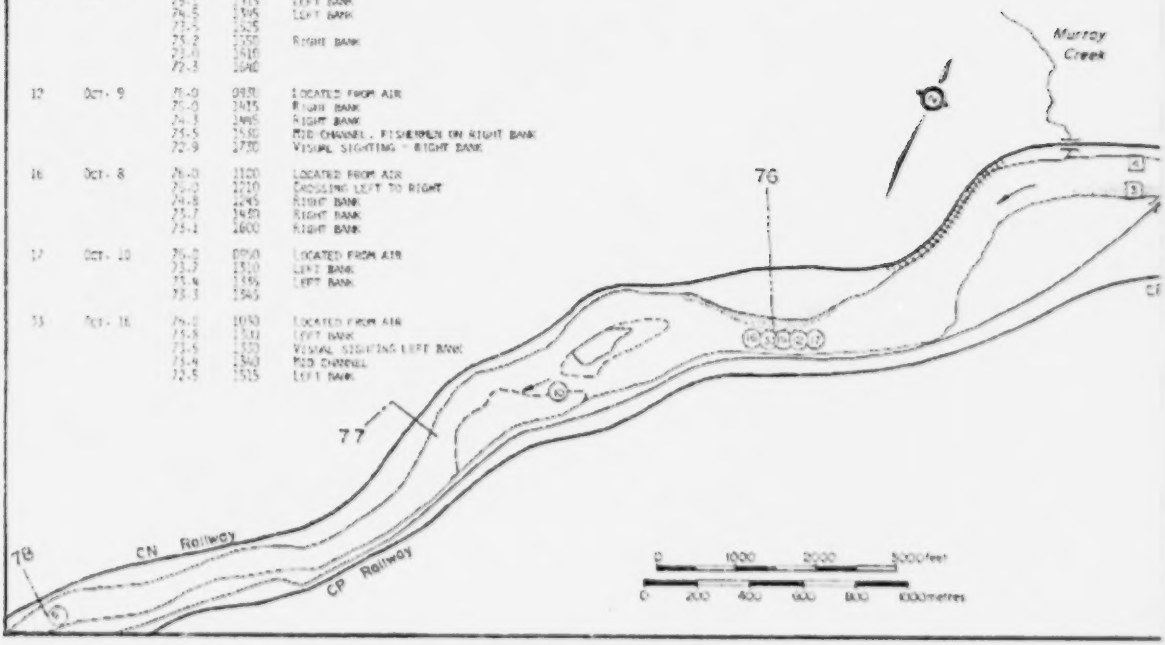
A preference was shown for the right bank by five of the seven radio tagged fish monitored through the area of the proposed encroachment from CN MP 73.5 to 72.9. The remaining two fish tracked through this area were located on the left bank opposite the encroachment site. One of these (#33) was visually tracked from CN MP 73.8 to 73.5 and the other (#17) was last located off the mouth of the Nicola River at CN MP 73.3.

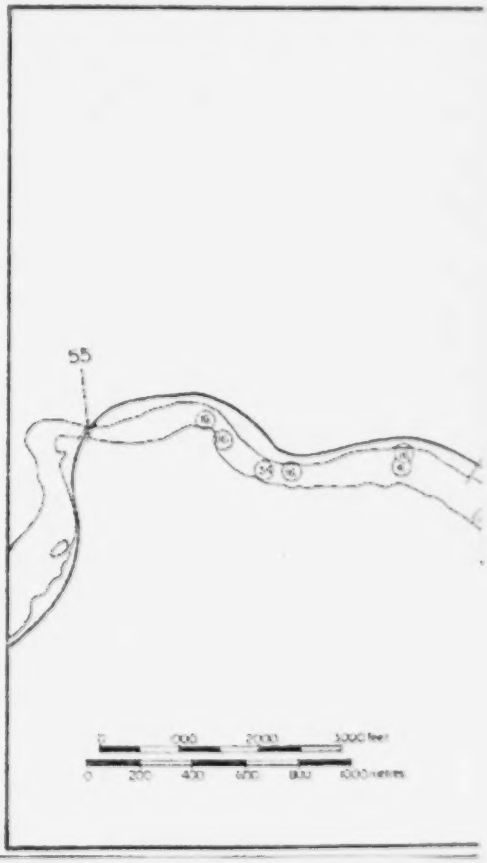
3.2.2 Section 2 CN MP 55-50 (Upper Black Canyon)

In this section, the Thompson River is deeply incised into valley fills comprised mainly of silt with some bedrock outcrops. The river meanders in a regular pattern from Ashcroft (CN MP 49.0) to the downstream end of Upper Black Canyon (CN MP 54.0). The railway follows the right bank throughout this section entering a tunnel at CN MP 51.5 and skirting a high valley wall between CN MP 52.0 and 53.0. The valley is characterized by black soils for which the canyon is named. A bedrock outcropping at the tunnel entrance (CN MP 51.4) extends across the river and creates a short section of rapids under normal flow conditions. In 1982, on the left bank opposite CN MP 53.0, there was a major rotational failure in the hillside supporting CPR tracks. As a result, a portion of the river bed adjacent to the left bank was uplifted as much as 3 m. The right bank is generally under constant attack by the river throughout this section which results in oversteepened fills. River encroachments will be major in areas such as this where the new track is to be constructed on the river side of the existing track. For that reason, this area was initially selected as a study site.

Four fish (#4, 16, 33 and 34) were tracked through this section of the river (Figure 12). A summary of travel rates has been derived from time/distance data presented in Figure 12:

Flight	Date	CN-CP	Time	Comments
6	Oct. 7	76-0	0910	LOCATED FROM AIR
		74-0	1220	
		75-1	1430	LOCATED ON RIGHT BANK
		73-0	1445	RIGHT BANK
9	Oct. 7	76-0	1220	
		74-0	1521	RIGHT BANK
		74-0	1540	RIGHT BANK
		75-5	1505	OPPOSITE NICOLA RIVER
		73-0	1550	
10	Oct. 5	76-5	1135	LEFT BANK
		75-1	1315	LEFT BANK
		74-6	1506	LEFT BANK
		73-5	1525	
		75-2	1550	RIGHT BANK
		73-0	1610	
		72-3	1640	
12	Oct. 9	76-0	0930	LOCATED FROM AIR
		75-0	1435	RIGHT BANK
		74-3	1445	RIGHT BANK
		75-5	1550	MID CHANNEL - FISHERMEN ON RIGHT BANK
		72-9	1720	VISUAL SIGHTING - RIGHT BANK
16	Oct. 8	76-0	1120	LOCATED FROM AIR
		75-0	1210	CROSSING LEFT TO RIGHT
		74-8	1245	RIGHT BANK
		75-7	1420	RIGHT BANK
		73-1	1600	RIGHT BANK
17	Oct. 10	76-0	0950	LOCATED FROM AIR
		73-7	1520	LEFT BANK
		75-4	1445	LEFT BANK
		73-3	1545	
33	Oct. 16	76-0	1030	LOCATED FROM AIR
		75-8	1330	LEFT BANK
		73-5	1520	VISUAL SIGHTING LEFT BANK
		73-9	1540	MID CHANNEL
		72-5	1535	LEFT BANK





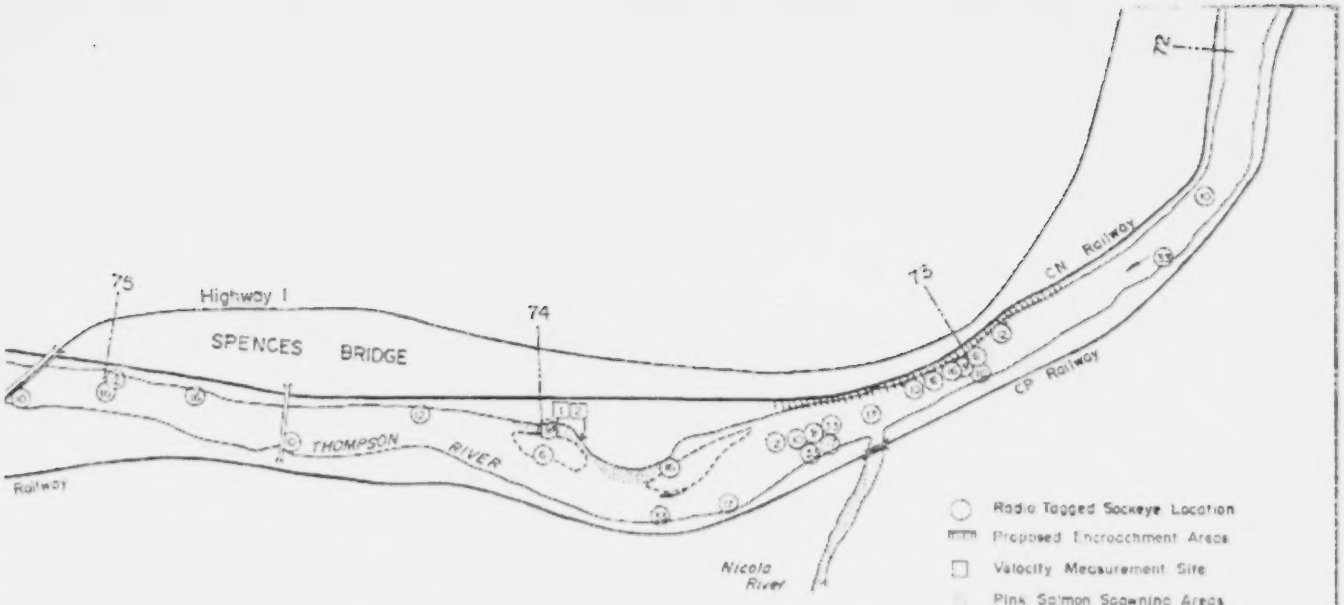
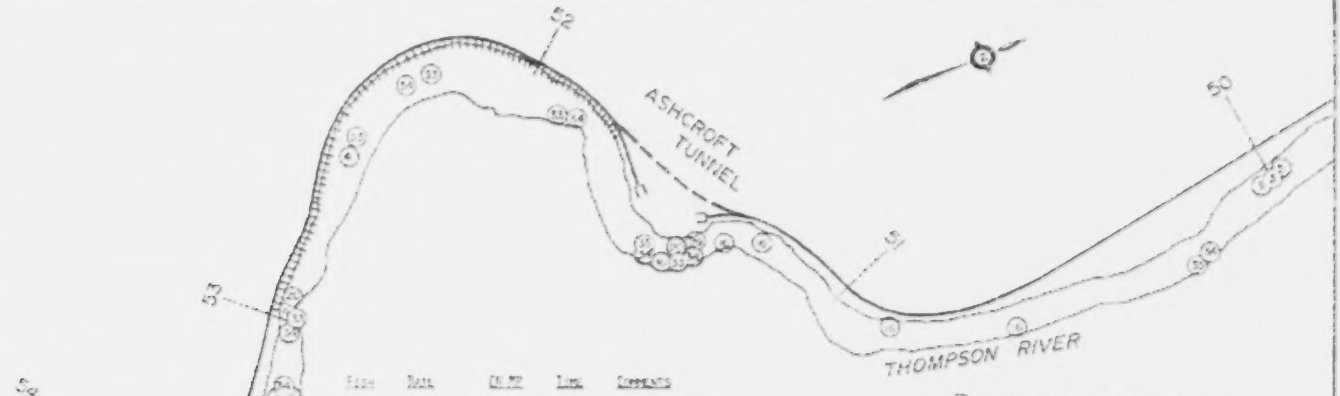


FIGURE 11
1982 DETAILED TRACKING
CN MP 78-72
(SPENCES BRIDGE)



Fish	Date	CN MP	Time	Comments
3	Oct. 1	50.0	0900	LOCATED FROM AIR
4	Oct. 1	54.2	1625	IMMEDIATELY BELOW SLIDE SITE
		54.0	1645	POSTS VISIBLE THROUGH SLIDE SITE
		52.6	1805	ASSUME FISH ON RIGHT BANK
5	Oct. 1	50.0	0900	LOCATED FROM AIR
9	Oct. 4	50.0	0900	LOCATED FROM AIR
16	Oct. 12	54.5	1310	LEFT BANK VISUAL SIGHTING
		54.6	1700	LEFT BANK
		54.5	1750	
		54.2	1745	CROSSING TO RIGHT BANK
		53.9	1800	CROSSING TO LEFT BANK
		53.7	1315	LEFT BANK
		53.6	1500	CROSSED TO RIGHT BANK
		53.3	1400	RIGHT BANK
		53.2	1415	PIG CHANNEL
		53.3	1400	LEFT BANK
		51.5	1605	LEFT BANK - VISUAL SIGHTING
		51.9	1640	LEFT BANK - VISUAL SIGHTING
		51.2	1812	
		50.9	1750	RIGHT BANK
		50.7	1715	LEFT BANK
20	Oct. 12	53.0	1600	
		52.5	1750	
21	Oct. 14	51.5	1030	

Fish	Date	CN MP	Time	Comments
33	Oct. 17	54.0	1225	LEFT BANK
		52.9	1345	
		52.2	1300	
		51.9	1315	LEFT BANK
		51.5	1240	
		51.5	1355	LEFT BANK
		50.5	1400	LEFT BANK
34	Oct. 17	54.5	1100	LOCATED BY AIR
		53.2	1240	
		53.0	1215	
		52.8	1600	PIG CHANNEL
		51.9	1245	LEFT BANK
		51.5	1525	LEFT BANK AT RAPIDS
		51.4	1330	LEFT BANK
		50.5	1440	LEFT BANK

FIGURE 12
1982 DETAILED TRACKING
CN MP 55-50
(UPPER BLACK CANYON)

Table 6 Comparative Bank Counts of Sockeye in the Thompson River.

Location CN MP	No. of Fish/Min Right Bank	Left Bank	Time	Date
88.0	-	80	1700	Oct. 5
88.0	-	64	0940	Oct. 8
88.0	-	78	1400	Oct. 9
87.5	-	85	-	Oct. 6
75.0	120	3	1800	Oct. 7
75.0	115	49	1300	Oct. 8
73.8	-	2	1505	Oct. 5
73.0	150	-	1600	Oct. 5
65.0	56	-	1130	Oct. 5
63.5	56	-	1345	Oct. 10
63.5	63	-	1200	Oct. 12
63.0	63	-	1105	Oct. 13
51.2	-	150	1654	Oct. 10
47.0	20	124	1030	Oct. 5
47.0	-	42	1320	Oct. 13
46.7	-	72	1345	Oct. 13
46.0	60	70	1500	Oct. 4
46.0	44	240	1345	Oct. 8
46.0	17	-	1445	Oct. 13
45.1	1	-	1415	Oct. 8
44.9	60	-	1420	Oct. 8
44.5	38	-	1530	Oct. 13
43.5	164	-	1715	Oct. 6
41.0	16	-	1210	Oct. 14
40.5	114	-	1500	Oct. 6
34.9	127	11	1430	Oct. 9

*Note: (-) denotes no observation made.

Fish #	CN MP	Rate (km/h)
4	54.2 - 52.6	4.4
16	54.9 - 50.7	1.1
33	53.0 - 50.3	1.7
34	53.2 - 50.3	1.6

The latter two fish were followed simultaneously from CN MP 53 to 50. Fish #33 and 34 were not associated with a specific side of the river until CN MP 51.9 where they were located on the left bank at the outside of a bend and they continued on this side to CN MP 50, where tracking was terminated.

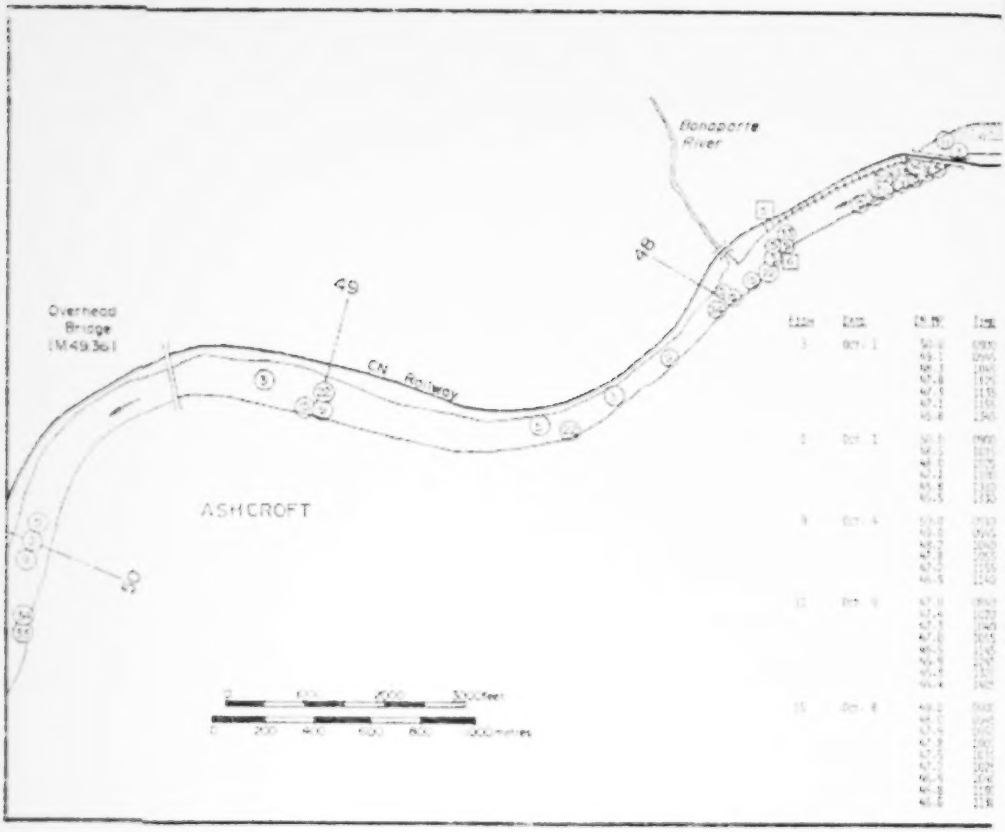
Fish #16 was observed to switch banks frequently. It was visually sighted and followed along the left bank from CN MP 51.5 to 51.3. This fish migrated at a slower rate through the high velocity water in the CPR slump area than the others, however, the difference was minor. Fish #16, the only one monitored through the proposed encroachment area from CN MP 53.3 to 53.5, maintained a position along the right bank.

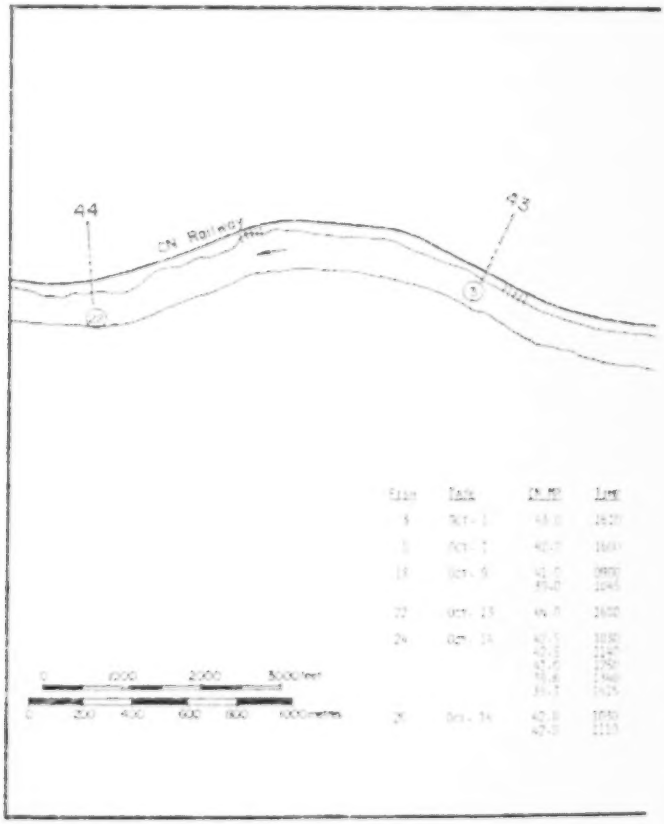
Three fish (#4, 33 and 34) were tracked through the proposed encroachment area between CN MP 53.0 and 51.8. Fish #4 was the only one located along the right bank adjacent to the encroachment, the others demonstrated a preference for the left bank.

3.2.3 Section 3 CN MP 50-44 (Ashcroft)

The river meanders in a regular pattern from CN MP 44.0 to Ashcroft at CN MP 50.0 and is utilized for spawning by pink salmon between CN MP 44.0 and 47.0 (Figure 13). Travelling in an upstream direction from Ashcroft Siding at CN MP 49.0, the CN line follows the right bank, crossing the Bonaparte River at CN MP 47.9 and the Thompson River at CN MP 47.1. From this point, the track swings away from the river channel on the left side until it again crosses the Thompson River at CN MP 45.8 to 44.0. The track is generally situated on existing river fill which is subject to active erosion resulting in oversteepened banks. The river channel is confined by the CN fills and those of a local road, as well as the CP rail tracks except in the area between the two crossings from CN MP 47.1 to 45.8. It then widens to include a broad flood plain and abuts a high valley wall on the right bank comprised mainly of silts.

This section of river was monitored frequently during the program due to its close proximity to Ashcroft and ease of


Bonaparte River
48
49
Overhead Bridge (M49361)
CN Railway
ASHCROFT
47


44
CN Railway
43

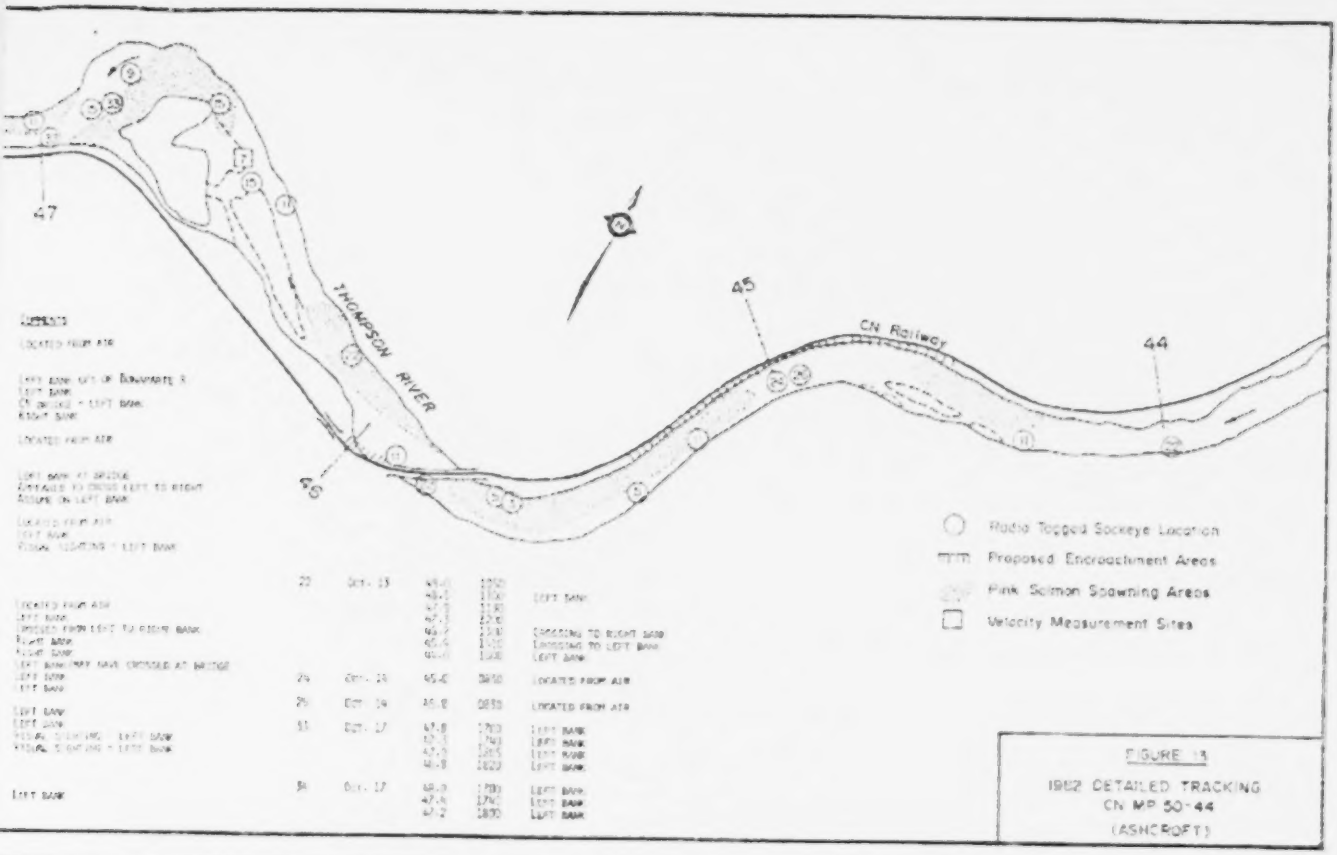


FIGURE 13

1982 DETAILED TRACKING
CN MP 50-44
(ASHCROFT)

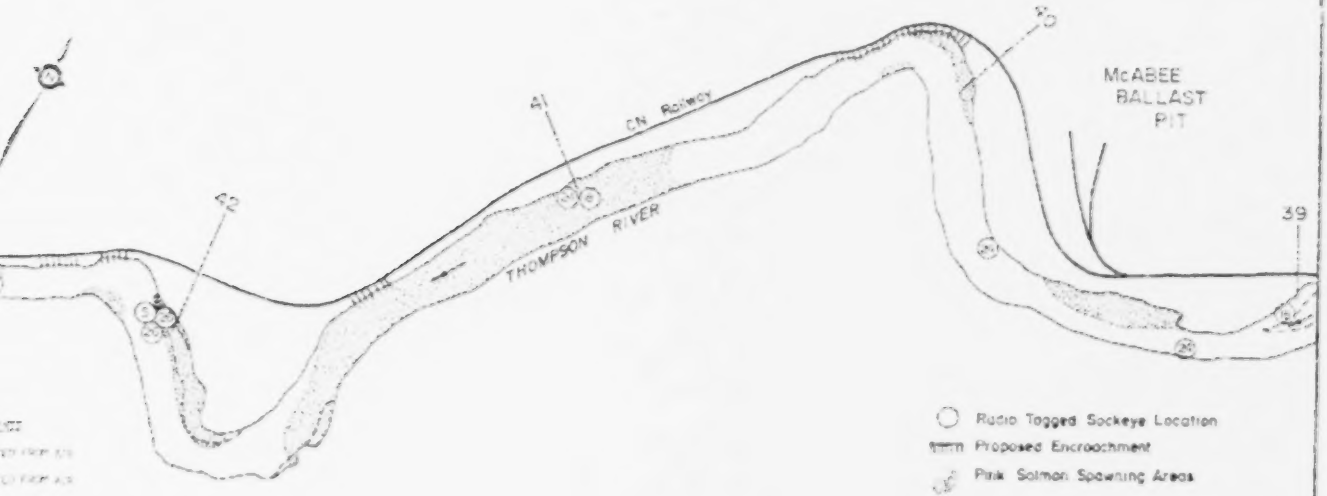


FIGURE 14

1982 DETAILED TRACKING
CN MP 44 - 39
(McABEE)

access. Eight fish (#3, 5, 9, 11, 15, 22, 33 and 34) were tracked through this area (Figure 13). Fish #9 and 15 were visually located near CN MP 48.0 by sighting Peterson disc tags. The fish generally migrated along the left bank or in the middle of the channel. Most fish continued to follow the left bank along a large cobble bar to CN MP 46.5 where they appeared to split and utilize both sides from CN MP 46.5 to 45.5. At the bridge crossing (CN MP 45.8), fish #11 and 22 had shifted from the right bank to the left.

There are three proposed encroachment areas in this section of the river. Between CN MP 47.3 and 47.7, an encroachment will extend from the Bonaparte River to the CNR bridge. This deep narrow reach is bordered on both sides by steep rip-rap banks. All fish tracked in this area were located along the left bank opposite the proposed encroachment site. Fish counts made immediately upstream of the encroachment site (CN MP 47) showed that 86% of the migrants enumerated on October 5 travelled along the left bank (Table 6).

Another proposed encroachment site is located at CN MP 46.0, immediately downstream from the CNR bridge at CN MP 45.8. A backwater pool is situated at the base of the existing CN fill (Reid, Crowther and Partners Limited, 1982). Fish counts made from both banks on October 4 showed a 75% preference for the left bank (Table 6).

The proposed encroachment from CN MP 45.4 to 44.6 follows the outside bend of the river. Both of the fish (#5 and 11) tracked through this area migrated along the left bank.

3.2.4 Section 4 CN MP 44-39 (McAbee)

Between CN MP 44 and 39, the Thompson River meanders through valley fill comprised primarily of silts with some alluvial terraces and occasional bedrock. The CN track is located on the right bank of the river throughout this section and existing fills are currently under attack from river erosion between CN MP 44 and 43, and between CN MP 41 and 40. McAbee Ballast Pit is located at the upstream end of the section (CN MP 39).

Five fish (#5, 18, 22, 24, 26) were located in this section (Figure 14). However, infrequent sightings made migratory trends difficult to establish. Fish were sighted on the right bank near CN MP 44 but further upstream sightings were on the left bank with one exception. Fish #24 crossed over from left to right and again from right to left between CN MP 39.5 and 39.0.

Proposed encroachments are located at CN MP 40.1, 41.5, 42.2, 42.3, 42.9, and 43.6. The first two encroachments are situated adjacent to pink salmon spawning areas which have been identified between CN MP 39.2 and 39.5, CN MP 39.9 and 40.1, CN MP 40.8 and 41.6, and CN MP 41.8 and 42.0 (IPSFC records, 1981), (Figure 14). The proposed encroachment site at CN MP 42.2 has a steeply sloped bank which is subject to active river erosion. Holding pools are located at the base of the existing embankment which may be used by steelhead trout and migrating adult salmon (Reid, Crowther and Partners Limited, 1982). Radio tagged fish (#24 and 26) monitored through this area were found to utilize the right bank containing these holding areas.

3.2.5 Section 5 CN MP 39-34 (Anglesey)

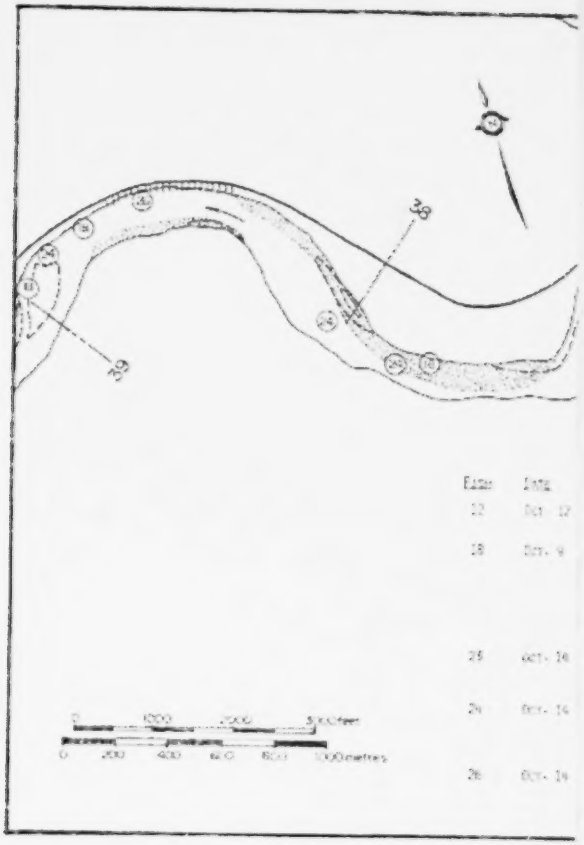
The Thompson River in this section meanders in a regular pattern, characterized by alluvial terraces and fans on the right bank, and glacial out washes, bedrock, thin colluvium and till on the left bank. The CN track is located on the right bank between CN MP 39 and 34 then crosses to the left bank by a bridge which is skewed to the river channel at the downstream end of a bend. Active erosion has been identified along the right bank between CN MP 34.7 and 34.8, CN MP 35.2 and 35.9, and at the outside of the bends from CN MP 36.9 to 37.5 and CN MP 38.1 to 39.0.

The five fish (#12, 18, 23, 24 and 26) followed in this section of the river (Figure 15) were generally found to migrate along the right bank. One fish (#23) crossed to the left bank at CN MP 34.5. Fish #18 was tracked at seven locations along the right bank between CN MP 39 and 34.8. This fish and fish #24 were found to have slower migration speeds (1.4 km/hr and 1.3 km/hr, respectively) through this section than in adjacent sections where speeds of 1.93 km/hr were recorded for each individual. Fish counted on October 9 at CN MP 34.9 (Table 6) totalled 138, with 127 fish (92%) choosing the right bank and 11 fish (8%) choosing the left side.

Proposed encroachment sites are located at CN MP 34.8, 35.6, 37.0, 37.3, and 38.7, none of which conflict directly with the known pink salmon spawning areas generally associated with inside bends of the river in this section (IPSFC records, 1981) (Figure 15).

3.2.6 Section 6 CN MP 34-30 (Walhachin)

In this section, the Thompson River follows a regular meandering pattern through areas comprised mainly of glacial outwash


38
39
Date
Oct. 12
Oct. 9
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200
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Date
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34
0
200

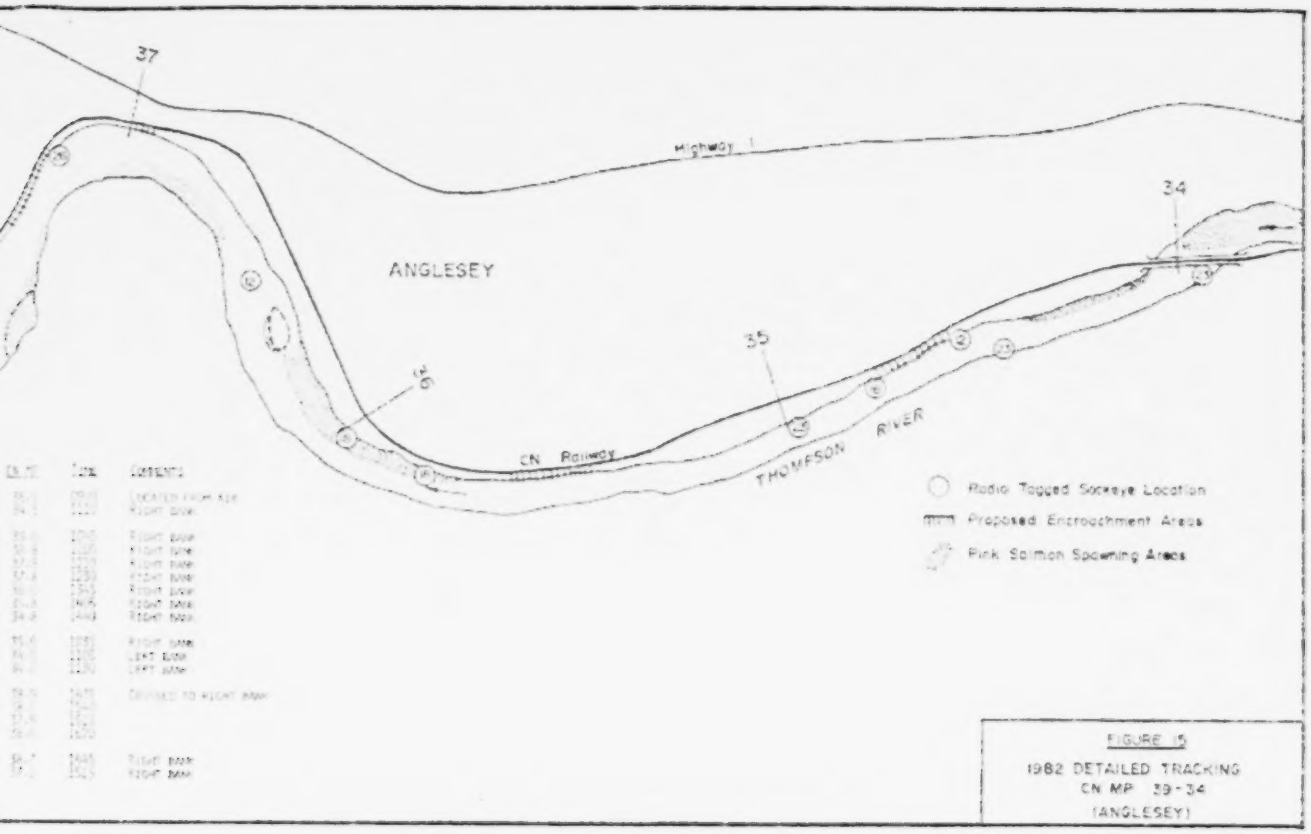

FIGURE 15
1982 DETAILED TRACKING
CN MP 39-34
(ANGLESEY)

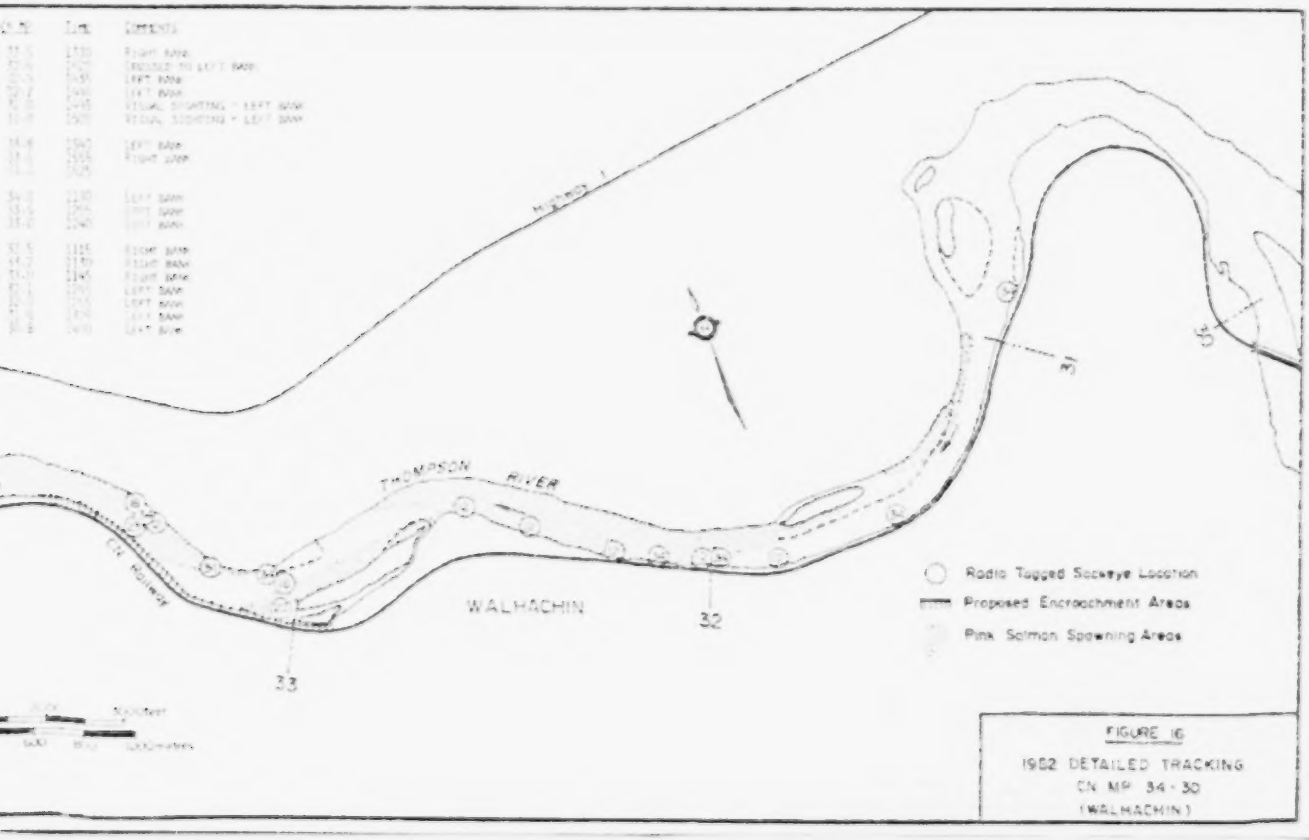

FIGURE 16
1982 DETAILED TRACKING
CN MP 34-30
(WALHACHIN)

material with pockets of alluvial terrace and a short section of bedrock with thin colluvium and till. The CN track is located on the left bank throughtout this section. Its embankments are under hydraulic attack from CN MP 31 to 32.2 and CN MP 33 to 34. A long encroachment is proposed throughout the latter stretch which also conflicts with known pink salmon spawning (IPSFC records, 1981) (Figure 16). High water velocities are associated with the railway bridge piers at CN MP 34 (Reid, Crowther and Partners Limited, 1982).

Four fish (#12, 18, 23, 24) were monitored in this river section (Figure 16). All fish were located at least once between CN MP 34 and 33 and only one (#23) was found to migrate along the left bank in this area. Two fish (#12 and 34) crossed over from the right bank to the left between CN MP 33 and 32, and continued along the left side for the duration of the track. Fish #12 was located visually on two occasions. The migration rates of fish #12, 18, and 23 decreased in the vicinity of the CN bridge at CN MP 34 as shown in the following summary and as derived from time/distance recordings in Figures 15 and 16:

Fish #	Migration Rate (km/hr)		
	Downstream	CNR Bridge	Upstream
12	0.92	0.43	1.02
18	1.69	1.00	1.07
23	1.09	0.85	-
mean	1.23	0.76	1.05

3.3 GENERAL OBSERVATIONS

Visual observations of migrating fish can provide insight into migratory behaviour relative to flow patterns and bank configuration. In most cases, such observations must be regarded as only a partial representation of the total picture since the observer can never be certain if all of the fish are visible. The following observations are presented with full recognition of this uncertainty and are organized in an attempt to characterize migration along three types of banks: shallow slope gravel or cobble bars; moderate to steep slope, rip-rap or boulder; and steep boulder or bedrock slopes.

3.3.1 Shallow Slope Gravel or Cobble Bars

Migration along typical shallow sloped bars mainly upstream of Spences Bridge was easily observed from the air, from bridges

and from high points of land such as the adjacent highway. Fish were frequently seen migrating in a discrete band which may have represented a zone of preferred depth, velocity, and distance from shore, among other parameters. The discrete band of fish was especially visible from the airplane. Fish generally swam three to eight abreast in a band about 1.5 to 3 m wide. In broad sections of the river, the band was generally formed well out from shore (more than 4.5 m) in an area shallower than the deepest part of the river. Generally, the river bottom could be seen beyond the location of the fish so it is safe to conclude that the observed band of fish was not just the shallowest edge of a large school of fish extending into the deeper part of the river. Also, the bottom was not visible at the deepest section of the river so it cannot be stated with certainty that fish were not actively migrating there as well. However, the discrete nature of the observed bands of fish would argue against this possibility. Generally, it appeared from the relatively wide area through which the fish were seen migrating that the zone of preferred velocities was relatively broad.

3.3.2 Moderate to Steep Slope, Rip-Rap or Boulder Banks

Fish migrating through medium velocities along steeper sloped banks were observed much closer to the shoreline than those observed along shallow sloping banks. Generally, the fish swam up to three abreast in a band 0.5 to 2.0 m wide. Often, the plane of the band of fish could be seen to slope away parallel to the bottom. The river bottom could sometimes be seen beyond the band of fish suggesting that the band did not extend further into deep water.

In certain areas, moderate to steeply sloping banks occurred adjacent to slack water. The fish were generally found in a discrete band along the shear zone between the slack water and main current, likely due to preferred depth and velocity. The band was generally less than 1.5 m wide with up to three fish abreast. The swimming depth ranged downward from 0.5 m. The lower limit could not be determined with any certainty due to poor visibility.

3.3.3 Steep Boulder or Bedrock Banks

Fish migrating through high velocities along steep bedrock or boulder banks (e.g. Thompson Rapids) were observed to exhibit alternating swimming behaviours. Fish generally swam in single file close to shore in the high velocity water around rock out-

crops. Then, since burst speed swimming cannot be maintained for a prolonged length of time (Bell, 1973), the fish tended to hold in schools in back eddies and pools of slower water. The turbulent nature of the water precluded the observation of fish in areas other than at the shoreline.

In medium velocity water, the swimming behaviour was very similar to that of fish along moderate to steeply sloping rip-rap banks. The fish tended to be found in discrete bands in the shear zone representing a preferred velocity.

3.4 DISCUSSION

These observations have implications with respect to potential encroachments into the river. Significant restriction of the river channel and increases in velocity, potentially result in decreased migration rate as well as overnight or prolonged delay depending upon the severity of conditions. The observed migration rates indicate that migration through the Fraser Canyon and lower section of the Thompson River is already substantially slower than through the upper Thompson (Table 2, Figure 3). In addition, encroachments in the upper Thompson would not likely constrict the river to such an extent that migration rates would be reduced to the rates observed in the Fraser Canyon or cause short term delay as at the Thompson Rapids. Such reduced rates would be extremely undesirable.

The migration rates and behaviour monitored during this study provide a basis for future comparison should the river configuration be substantially altered. However, different discharge conditions would be expected to alter migration conditions. The Thompson River mean discharge at Spences Bridge during the October 1982 study was 637 m^3/s (Appendix III) substantially higher than the 1951-79 mean of 493 m^3/s (Water Survey of Canada records).

4.0 VELOCITY MEASUREMENTS AND OBSERVATIONS

Salmon have been observed to utilize specific corridors for upstream migration in rivers. Generally, the fish prefer the lower velocities and varied flow patterns associated with river margins (Jackson, 1950). Therefore, the nature of velocities experienced by the fish is important to address potential problems with fish migration or develop mitigative design criteria at encroachment sites.

During the period of study, the salmon showed a preference for migrating along river margins and, in some instances, a preference for one side of the river over the other. To document physical conditions present in the water during the time fish were utilizing these corridors, measurements of water velocity were taken at locations that were considered typical of areas where fish exhibited a migration preference. Seven sites were selected (Figures 11 and 13) and average water velocities were measured either with a current meter or by timing the travel of a floating object between two fixed points, approximately 6 m offshore.

4.1 EQUIPMENT AND METHODS

A Marsh McBirney Model 201 M portable water current meter was attached to a wading rod and positioned by hand to record velocities. Water depth at each location was measured with the wading rod and the transducer adjusted vertically to 0.6 of the depth so that it would record the average velocity in the water column at that point. The transducer was held in this position for at least 30 seconds until the velocity reading stabilized. Fluctuations were noted as well. The average velocity provides an index of the velocities along the migration path on a particular bend. However, the "nose" or opposing velocity which the fish is facing would tend to be lower than the average, especially for depths greater than 0.3 meters.

Where it was found that fish preferred to migrate along one side of the river as opposed to the other, velocity measurements were recorded on both sides for comparison. Additional water velocities were estimated further out in the river channel at some locations (Sites 3, 4, 5, and 6) by recording the transit time of a floating object between two points. The distance between the two points was estimated by pacing therefore, the significance of the results should be viewed accordingly.

4.2 RESULTS

Average velocities at the seven sites ranges from 0.34 - 1.00 m/s (Table 7). Individual sites are discussed in following sections.

Table 7 Velocity Measurements at Selected Sites Within Study Area, (Refer to Figures 11 and 13).

Date	Site	Bank	CNR Mile	Average Velocity (m/s)	Distance from Shore (m)	Water Depth (m)	Surface Velocity[1] (m/s)
Oct. 1	1	R	74.0	0.34	0.76	0.61	-
Oct. 1	2	R	74.0	1.01	0.76	0.40	-
Oct. 18	3	L	75.1	0.46	3.05	0.52	0.76
Oct. 18	4	R	75.1	0.61	0.91	0.37	1.10
Oct. 18	5	R	47.8	0.46	1.52	0.64	1.01
Oct. 18	6	L	47.8	0.40	0.91	0.88	1.52
Oct. 18	7	L	46.7	0.49	0.21	0.79	-

[1] Surface velocities are estimates derived by timing floating objects about 6 m from the shoreline.

4.2.1 CN MP 74.0 - Sites 1 and 2

Sites 1 and 2 were located in a side channel on the right bank of the Thompson River at Spences Bridge (Figure 11). The side channel is situated on the inside of a gentle bend in the river and fronted by a gravel bar which is exposed during lower flows. The channel dried completely during the latter stages of the study. Salmon were observed in concentrated numbers along the right bank of the side channel immediately adjacent to the shoreline. Eighty-eight percent of the fish counted between CN MP 75 and 73, were seen along the right bank (Table 6). A definite pattern of movement was evident in an area characterized by riffles followed by a long stretch of calmer water. Salmon accumulated in a broad band along the shoreline in the lower velocity zone, moved generally single file through the area of faster water then accumulated again in another lower velocity zone. Water velocity (Table 7) measured in the riffle area of site 2 was three times that measured in the low velocity zone, site 1, (1.0 m/s and 0.3 m/s respectively). Considering an estimated migration speed of 0.3 m/s over the riffle area, the fish were required to change from cruising speed to sustained speed as defined by Bell (1973) (Table 8).

Table 8 Relative Swimming Speeds (m/s) of Average Size Adult Fish (Bell, 1973).

Species	Cruising Speed	Sustained Speed	Burst Speed
Sockeye	0 - 1.0	1.0 - 3.1	3.1 - 6.3
Steelhead	0 - 1.4	1.4 - 4.2	4.2 - 8.1

4.2.2 CN MP 75.1 - Sites 3 and 4

Sites 3 and 4 were located in the main channel of the Thompson River approximately 30 m downstream from the Trans Canada Highway at Spences Bridge. Site 3 was situated on the left bank and site 4 on the right bank. Fish counts (Table 6) indicate that most fish preferred to migrate along the right bank at the bridge. The thalweg of the channel, located approximately midstream although the channel, was generally deeper along the left side (site 3) than the right side (site 4). The velocity measurement at site 3 was taken from a small gravel bar formed in an embayment below the bridge. Water velocities (Table 7) were slightly higher on the right bank (0.6 m/s) than the left (0.5 m/s) but were still within the limits of cruising speed as defined by Bell (1973) (Table 8). Surface velocities estimated for the right and left banks were 1.1 m/s and 0.76 m/s respectively 6 meters from the banks (Table 7).

4.2.3 CN MP 47.8 - Sites 5 and 6

Sites 5 and 6 were located on the Thompson River approximately 60 m upstream from the mouth of the Bonaparte River (Figure 13). Site 5 was located on the right bank and site 6 on the left bank where the majority of salmon were observed to migrate (Table 6). The shoreline on the right bank was moderately sloped with boulders and cobbles while the left bank was steeply sloped and comprised of rip-rap forming the highway embankment. Salmon migrated along the left bank in a definite band of two to three fish abreast, immediately adjacent to the river margin. Average velocities measured with the current meter were similar (Table 7) on either side of the river (right bank 0.5 m/s, left bank 0.4 m/s) although surface velocity estimated by floating objects was higher on the left (1.0 m/s vs. 1.5 m/s). Nearshore velocities were within the limits of sockeye cruising speed and the fish were observed to swim at a steady pace through the area.

4.2.4 CN MP 46.7 - Site 7

Site 7 was located in an area of the Thompson River characterized by a broad floodplain. Measurements were taken from the left bank at the edge of a large gravel bar composed of medium sized cobbles. Salmon moved in a narrow band of two to three fish in width. An average velocity of 0.5 m/s was measured at the site (Table 7) which was within the limits of cruising speed for sockeye salmon (Bell, 1973).

4.3 DISCUSSION

4.3.1 Migration Behaviour

Generally fish migration was observed to be concentrated within a narrow zone immediately adjacent to the river banks. No visual sightings were made of fish migrating out in the center portion of the river channel except from the bridge at CN MP 46 where fish were observed to cross over from the left bank to the right bank. In addition, observations made during an aerial reconnaissance on October 11, 1982 to photograph and record migration patterns, failed to locate any fish in the main flow channel. However, visibility in the deeper portions of the channel was limited so these observations do not rule out the possibility that migration occurs throughout the river cross section. Further studies of fish migration behaviour should include an underwater survey of their distribution across the river using SCUBA.

4.3.2 Water Velocity

The portable water current meter was not adequate to sample conditions more than a few feet from shore because it had to be positioned by wading and holding the rod assembly by hand. This equipment does not have the flexibility to record velocities further out in the channel unless it can be suspended from an extendable arm positioned onshore or from a boat. Velocities recorded during the study were the theoretical mean measured at a fixed point in the water column and it may not accurately represent the velocity preferred by a fish having a choice of vertical position at the same location. In addition, the current meter does not measure current direction, thus it cannot accurately determine the precise conditions experienced by the fish. Further studies using a portable boom and a current meter with vector indicator should permit a better analysis of velocities as they relate to fish migration.

5.0 SUMMARY AND CONCLUSIONS

Studies described in this report were designed to provide preliminary information regarding behaviour of salmon migrating along various types of natural and rip-rapped banks and to develop appropriate techniques to obtain that information. The need for this migration information was created by expansion of the CN Rail plant to accommodate twin tracking of its rail line through the Fraser and Thompson River valleys. These river channels are paralleled by CN Rail, CP Rail and the Trans Canada Highway. Much of the river banks are already encroached upon by rip-rap material associated with the railway and highway. In some areas, twin tracking will result in further widening of the rail bed out into the river channel and will encroach on existing rip-rap as well as natural bank areas.

Twenty-one sockeye were captured, radio tagged and released at Saddle Rock near Yale, and similarly 13 sockeye and three steelhead at Lytton upstream of the Fraser-Thompson confluence. Migration rates of the fish were calculated by dividing the distance travelled by the elapsed time between sightings, established daily from a tracking airplane. Sockeye migration rates were relatively slow a day or two after tagging. The average delay attributed to the stress of capture and tagging was calculated at 17 hours. Migration rates increased progressively as the fish moved upstream, likely as a result of decreasing river gradient and associated reduced water velocity.

Apparent migration delays in the Fraser River were noted between Black Canyon and Scuzzy Rapids including areas immediately below and above Hells Gate. Thompson Rapids (CN MP 88-89) was the only observed point of delay in the Thompson River, with an average delay of 9.0 hours. As presently proposed, the twin tracking encroachments would not be expected to create additional obstruction or delay. Radio tracking results indicated that a relatively major constriction in the river would be required to create an obstruction to fish migration.

Steelhead tagged near the Fraser-Thompson confluence were not observed to migrate appreciable distances during the period of the study.

Detailed tracking of sockeye was successful in determining sockeye migration rates over short distances (1-5 km) and demonstrated that the fish frequently cross from bank to bank in the Thompson River. This tracking, however, was not suffi-

ciently detailed to permit a comparison of water velocities faced by the fish as they travelled past the various types of natural and encroached banks. The latter relationship would be required to predict the effect of encroachments upon the fishes' rate of energy utilization.

Detailed tracking did reveal an apparent reduction (by about 38%) in the migration rate of three fish at the CN Rail bridge at CN MP 34. The delay was likely associated with the higher velocities which occur in a short set of rapids at the bridge site.

Visual observations were made of sockeye migrating along three types of banks:

i) Shallow slope gravel or cobble bars where fish migrated in discrete bands approximately 1.5-3.0 m wide and several metres from shore;

ii) Moderate to steep slope rip-rap or boulder banks where fish swam closer to the shoreline in a narrow band approximately 0.5-2.0 m wide; and

iii) Steep boulder or bedrock banks where fish were forced by high velocities to swim single file close to the bank and to rest as schools in back eddies.

ACKNOWLEDGEMENTS

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APPENDIX I

Sockeye Radiotelemetry

Monitored in the Fraser/Thompson Rivers

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN RAIL MP	/SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
1	M	SEPT.28	1230	0.0	97	ASHCROFT	80	0	0.00
		SEPT.29	920	20.8	88	ASHCROFT	94	14	0.67
		SEPT.29	1600	6.7	88	ASHCROFT	94	0	0.00
		SEPT.30	845	16.8	76	ASHCROFT	114	20	1.19
		SEPT.30	1950	11.1	64	ASHCROFT	133	19	1.71
		OCT.1	915	13.4	51	ASHCROFT	152	19	1.42
		OCT.1	1555	6.7	44	ASHCROFT	165	13	1.94
2	F	SEPT.28	1240	0.0	97	ASHCROFT	80	0	0.00
		SEPT.29	920	20.7	88	ASHCROFT	94	14	0.68
		SEPT.29	1630	7.2	82	ASHCROFT	104	10	1.39
		SEPT.30	835	16.1	64	ASHCROFT	133	29	1.80
		OCT.1	900	24.4	34	ASHCROFT	181	48	1.97
3	F	SEPT.28	1305	0.0	97	ASHCROFT	80	0	0.00
		SEPT.29	920	20.3	89	ASHCROFT	93	13	0.64
		SEPT.29	1500	5.7	88	ASHCROFT	95	2	0.35
		SEPT.30	845	17.8	73	ASHCROFT	118	23	1.29
		SEPT.30	1955	11.2	62	ASHCROFT	136	18	1.61
		OCT.1	830	12.6	50	ASHCROFT	154	18	1.43
		OCT.1	1600	7.5	44	ASHCROFT	165	11	1.47
		OCT.2	835	16.6	28	ASHCROFT	192	27	1.63
4	M	SEPT.28	1320	0.0	97	ASHCROFT	80	0	0.00
		SEPT.29	920	20.0	90	ASHCROFT	92	12	0.60
		SEPT.29	1600	6.7	90	ASHCROFT	92	0	0.00
		SEPT.30	855	16.9	88	ASHCROFT	95	3	0.18
		OCT.1	920	24.4	61	ASHCROFT	137	42	1.72
		OCT.1	1655	7.6	53	ASHCROFT	150	13	1.71
		OCT.2	830	15.6	37	ASHCROFT	177	27	1.73
5	M	SEPT.28	1405	0.0	97	ASHCROFT	80	0	0.00
		SEPT.29	920	19.3	89	ASHCROFT	93	13	0.67
		SEPT.29	1500	5.7	88	ASHCROFT	95	2	0.35
		SEPT.30	840	17.7	73	ASHCROFT	118	23	1.30
		OCT.1	830	23.8	50	ASHCROFT	154	36	1.51
		OCT.1	1600	7.5	42	ASHCROFT	167	13	1.73
		OCT.2	835	16.6	26	ASHCROFT	197	30	1.81
6	F	SEPT.30	1740	0.0	97	ASHCROFT	80	0	0.00
		OCT.1	940	16.0	94	ASHCROFT	85	5	0.31
		OCT.1	1620	6.7	89	ASHCROFT	94	9	1.34
		OCT.2	910	16.8	78	ASHCROFT	110	16	0.95
		OCT.2	1530	6.3	72	ASHCROFT	118	8	1.27
		OCT.3	1100	19.5	64	ASHCROFT	132	14	0.72
		OCT.4	920	22.3	54	ASHCROFT	149	17	0.76
		OCT.4	1320	4.0	49	ASHCROFT	155	6	1.50
		OCT.5	840	19.3	33	ASHCROFT	182	27	1.40

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN RAIL MP	/SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
7	M	SEPT.30	1755	0.0	97	ASHCROFT	80	0	0.00
		OCT.1	940	15.8	93	ASHCROFT	86	6	0.38
		OCT.1	1620	6.7	89	ASHCROFT	94	8	1.19
		OCT.2	915	16.9	89	ASHCROFT	93	-1	-0.06
		OCT.2	1230	3.3	89	ASHCROFT	94	1	0.30
8	M	SEPT.30	1800	0.0	97	ASHCROFT	80	0	0.00
		OCT.1	940	15.7	93	ASHCROFT	86	6	0.38
		OCT.1	1620	6.7	89	ASHCROFT	93	7	1.04
		OCT.2	915	16.9	88	ASHCROFT	94	1	0.06
		OCT.3	1050	25.6	68	ASHCROFT	125	31	1.21
		OCT.4	935	22.8	48	ASHCROFT	157	32	1.40
		OCT.5	840	23.1	33	ASHCROFT	182	25	1.08
		OCT.5	1120	2.7	28	ASHCROFT	194	12	4.44
9	F	SEPT.30	1800	0.0	97	ASHCROFT	80	0	0.00
		OCT.1	940	15.7	95	ASHCROFT	83	3	0.19
		OCT.1	1620	6.7	89	ASHCROFT	93	10	1.49
		OCT.2	910	16.8	79	ASHCROFT	109	16	0.95
		OCT.2	1530	6.3	73	ASHCROFT	118	9	1.43
		OCT.3	1100	19.5	62	ASHCROFT	136	18	0.92
		OCT.4	910	22.2	50	ASHCROFT	155	19	0.86
		OCT.5	840	23.5	29	ASHCROFT	192	37	1.57
		OCT.5	1100	2.3	27	ASHCROFT	195	3	1.30
10	M	SEPT.30	1630	0.0	97	ASHCROFT	80	0	0.00
		OCT.1	940	17.2	97	ASHCROFT	80	0	0.00
		OCT.2	920	23.6	97	ASHCROFT	80	0	0.00
		OCT.2	1220	3.0	97	ASHCROFT	80	0	0.00
		OCT.3	1045	22.4	97	ASHCROFT	80	0	0.00
		OCT.4	955	23.2	90	ASHCROFT	91	11	0.47
		OCT.5	945	23.8	79	ASHCROFT	109	18	0.76
		OCT.5	1145	2.0	77	ASHCROFT	112	3	1.50
		OCT.5	1525	3.7	74	ASHCROFT	117	5	1.35
		OCT.6	1130	20.1	61	ASHCROFT	138	21	1.04
		OCT.6	1700	5.5	55	ASHCROFT	146	8	1.45
		OCT.7	1100	18.0	39	ASHCROFT	173	27	1.50
11	M	SEPT.30	1440	0.0	22	YALE	0	0	0.00
		OCT.1	1015	19.6	14	YALE	13	13	0.66
		OCT.2	950	23.4	10	YALE	19	6	0.26
		OCT.4	1020	48.5	115	ASHCROFT	51	32	0.66
		OCT.5	1005	23.8	99	ASHCROFT	77	26	1.09
		OCT.6	930	23.4	90	ASHCROFT	91	14	0.60
		OCT.6	1630	7.0	89	ASHCROFT	93	2	0.29
		OCT.7	950	17.3	77	ASHCROFT	112	19	1.10
		OCT.7	1820	8.5	70	ASHCROFT	123	11	1.29
		OCT.8	850	14.5	68	ASHCROFT	125	2	0.14
		OCT.8	1110	2.3	66	ASHCROFT	130	5	2.17
		OCT.9	840	21.5	49	ASHCROFT	155	25	1.16
		OCT.9	1405	5.4	44	ASHCROFT	163	8	1.48
		OCT.10	900	18.9	31	ASHCROFT	187	24	1.27

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN RAIL MP	/SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
12	F	SEPT.30	1415	0.0	22	YALE	0	0	0.00
		OCT.1	1015	20.0	16	YALE	10	10	0.50
		OCT.2	950	23.6	6	YALE	26	16	0.68
		OCT.2	1150	2.0	5	YALE	27	1	0.50
		OCT.3	1015	22.4	5	YALE	27	0	0.00
		OCT.4	1030	24.3	5	YALE	27	0	0.00
		OCT.6	1050	48.3	108	ASHCROFT	62	35	0.72
		OCT.7	1000	23.2	94	ASHCROFT	85	23	0.99
		OCT.8	915	23.3	89	ASHCROFT	93	8	0.34
		OCT.9	930	24.3	76	ASHCROFT	114	21	0.86
		OCT.9	1730	8.0	73	ASHCROFT	118	4	0.50
		OCT.10	945	16.3	68	ASHCROFT	125	7	0.43
		OCT.10	1120	1.6	67	ASHCROFT	128	3	1.88
		OCT.11	850	21.5	53	ASHCROFT	150	22	1.02
		OCT.11	1600	7.2	47	ASHCROFT	160	10	1.39
		OCT.12	900	17.0	37	ASHCROFT	176	16	0.94
		OCT.12	1500	6.0	32	ASHCROFT	184	8	1.33
13	M	SEPT.30	1500	0.0	22	YALE	0	0	0.00
		OCT.1	1015	19.3	17	YALE	8	8	0.41
		OCT.2	945	23.5	10	YALE	19	11	0.47
		OCT.3	950	24.1	5	YALE	27	8	0.33
		OCT.4	1020	24.5	115	YALE	51	24	0.98
		OCT.5	1130	25.2	100	YALE	75	24	0.95
		OCT.6	930	22.0	88	ASHCROFT	94	19	0.86
		OCT.6	1515	5.8	89	ASHCROFT	93	-1	-0.17
		OCT.7	950	18.6	78	ASHCROFT	110	17	0.91
		OCT.7	1820	8.5	70	ASHCROFT	123	13	1.53
		OCT.8	1120	17.0	56	ASHCROFT	144	21	1.24
		OCT.8	1720	6.0	50	ASHCROFT	154	10	1.67
		OCT.9	850	15.5	36	ASHCROFT	178	24	1.55
		OCT.9	1305	4.3	31	ASHCROFT	187	9	2.09
14	F	SEPT.30	1500	0.0	22	YALE	0	0	0.00
		OCT.1	1015	19.3	10	YALE	19	19	0.98
		OCT.2	940	23.4	1	YALE	34	15	0.64
		OCT.3	935	23.9	104	ASHCROFT	69	35	1.46
		OCT.4	950	24.3	89	ASHCROFT	94	25	1.03
		OCT.5	1210	26.3	65	ASHCROFT	131	37	1.41
		OCT.5	1335	1.4	64	ASHCROFT	133	2	1.43
		OCT.6	845	19.2	46	ASHCROFT	162	29	1.51
15	M	SEPT.30	1515	0.0	22	YALE	0	0	0.00
		OCT.1	1015	19.0	17	YALE	8	8	0.42
		OCT.2	945	23.5	4	YALE	29	21	0.89
		OCT.3	1035	24.8	117	ASHCROFT	48	19	0.77
		OCT.4	1010	23.6	107	ASHCROFT	64	16	0.68
		OCT.5	955	23.8	92	ASHCROFT	90	26	1.09
		OCT.5	1755	8.0	89	ASHCROFT	93	3	0.38
		OCT.6	930	15.6	89	ASHCROFT	93	0	0.00
		OCT.6	1445	5.3	89	ASHCROFT	93	0	0.00
		OCT.7	1150	21.1	63	ASHCROFT	133	40	1.90
		OCT.8	840	20.8	49	ASHCROFT	155	22	1.06
		OCT.8	1130	2.8	47	ASHCROFT	160	5	1.79
		OCT.9	855	21.4	30	ASHCROFT	189	29	1.36

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN MP	RAIL /SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
16	F	OCT.3	1230	0.0	97	ASHCROFT	80	0	0.00
		OCT.4	1000	21.5	97	ASHCROFT	80	0	0.00
		OCT.5	1000	24.0	94	ASHCROFT	85	5	0.21
		OCT.5	1800	8.0	90	ASHCROFT	93	8	1.00
		OCT.6	1445	20.8	90	ASHCROFT	91	-2	-0.10
		OCT.7	955	19.2	89	ASHCROFT	93	2	0.10
		OCT.7	1705	7.2	85	ASHCROFT	99	6	0.83
		OCT.8	910	16.1	77	ASHCROFT	112	13	0.81
		OCT.9	920	24.2	68	ASHCROFT	125	13	0.54
		OCT.10	940	24.3	56	ASHCROFT	144	19	0.78
		OCT.10	1735	7.9	51	ASHCROFT	154	10	1.27
		OCT.11	845	15.2	48	ASHCROFT	157	3	0.20
		OCT.11	1615	7.5	46	ASHCROFT	162	5	0.67
		OCT.12	915	17.0	52	ASHCROFT	152	-10	-0.59
		OCT.12	1200	2.8	52	ASHCROFT	152	0	0.00
17	M	OCT.3	1245	0.0	97	ASHCROFT	80	0	0.00
		OCT.5	1000	45.3	97	ASHCROFT	80	0	0.00
		OCT.6	1000	24.0	98	ASHCROFT	78	-2	-0.08
		OCT.7	1005	24.1	97	ASHCROFT	80	2	0.08
		OCT.8	930	23.4	97	ASHCROFT	80	0	0.00
		OCT.9	1100	25.5	93	ASHCROFT	86	6	0.24
		OCT.10	950	22.8	76	ASHCROFT	114	28	1.23
		OCT.10	2000	10.2	68	ASHCROFT	125	11	1.08
		OCT.11	915	13.3	61	ASHCROFT	138	13	0.98
		OCT.11	1600	6.8	56	ASHCROFT	144	6	0.88
		OCT.12	845	16.8	50	ASHCROFT	155	11	0.65
		OCT.12	1215	3.5	47	ASHCROFT	160	5	1.43
18	M	OCT.3	1305	0.0	97	ASHCROFT	80	0	0.00
		OCT.5	1000	44.9	95	ASHCROFT	83	3	0.07
		OCT.6	1000	24.0	89	ASHCROFT	93	10	0.42
		OCT.6	1620	6.3	89	ASHCROFT	93	0	0.00
		OCT.7	950	17.5	78	ASHCROFT	110	17	0.97
		OCT.8	845	22.9	61	ASHCROFT	138	28	1.22
		OCT.9	900	24.3	41	ASHCROFT	170	32	1.32
		OCT.9	1625	7.4	33	ASHCROFT	182	12	1.62
19	F	OCT.4	1220	0.0	22	YALE	0	0	0.00
		OCT.5	1045	22.4	12	YALE	16	16	0.71
		OCT.6	1000	23.3	4	YALE	29	13	0.56
		OCT.8	1050	48.8	97	ASHCROFT	80	51	1.05
		OCT.9	940	22.8	90	ASHCROFT	91	11	0.48
		OCT.10	950	24.2	77	ASHCROFT	112	21	0.87
		OCT.11	915	23.4	60	ASHCROFT	139	27	1.15
		OCT.11	1800	8.8	51	ASHCROFT	152	13	1.48
		OCT.12	900	15.0	36	ASHCROFT	178	26	1.73

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN MP	RAIL /SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
20	F	OCT.4	1245	0.0	22	YALE	0	0	0.00
		OCT.5	1045	22.0	13	YALE	14	14	0.64
		OCT.6	1000	23.3	3	YALE	30	16	0.69
		OCT.7	1045	24.8	117	ASHCROFT	48	18	0.73
		OCT.8	940	22.9	105	ASHCROFT	67	19	0.83
		OCT.9	940	24.0	97	ASHCROFT	80	13	0.54
		OCT.10	1000	24.3	88	ASHCROFT	94	14	0.58
		OCT.11	930	23.5	76	ASHCROFT	114	20	0.85
		OCT.11	1545	6.3	70	ASHCROFT	123	9	1.43
		OCT.12	930	17.8	60	ASHCROFT	139	16	0.90
		OCT.12	1730	8.0	52	ASHCROFT	152	13	1.63
		OCT.13	1300	19.5	38	ASHCROFT	174	22	1.13
21	F	OCT.4	1300	0.0	22	YALE	0	0	0.00
		OCT.5	1045	21.8	17	YALE	8	8	0.37
		OCT.6	1015	23.5	9	YALE	21	13	0.55
		OCT.8	1000	47.8	1	YALE	34	13	0.27
		OCT.9	950	23.8	109	ASHCROFT	61	27	1.13
		OCT.10	1000	24.2	88	ASHCROFT	94	33	1.36
22	M	OCT.4	1310	0.0	22	YALE	0	0	0.00
		OCT.5	1045	21.6	12	YALE	16	16	0.74
		OCT.6	1000	23.3	4	YALE	29	13	0.56
		OCT.7	1030	24.5	115	ASHCROFT	51	22	0.90
		OCT.8	940	23.2	104	ASHCROFT	69	18	0.78
		OCT.9	940	24.0	91	ASHCROFT	90	21	0.88
		OCT.10	1005	24.4	88	ASHCROFT	94	4	0.16
		OCT.10	2000	9.9	85	ASHCROFT	101	7	0.71
		OCT.11	930	13.5	77	ASHCROFT	112	11	0.81
		OCT.11	1540	6.2	73	ASHCROFT	118	6	0.97
		OCT.12	930	17.8	63	ASHCROFT	133	15	0.84
		OCT.13	1100	25.5	49	ASHCROFT	157	24	0.94
		OCT.13	1600	5.0	44	ASHCROFT	165	8	1.60
		OCT.14	1040	18.7	30	ASHCROFT	189	24	1.28
23	F	OCT.4	1320	0.0	22	YALE	0	0	0.00
		OCT.5	1045	21.4	9	YALE	21	21	0.98
		OCT.8	945	71.0	107	ASHCROFT	64	43	0.61
		OCT.11	930	71.8	77	ASHCROFT	112	48	0.67
		OCT.11	1540	6.2	73	ASHCROFT	118	6	0.97
		OCT.12	930	17.8	65	ASHCROFT	131	13	0.73
		OCT.13	1050	25.3	49	ASHCROFT	155	24	0.95
		OCT.13	1610	5.3	44	ASHCROFT	165	10	1.89
		OCT.14	1035	18.4	35	ASHCROFT	179	14	0.76
		OCT.14	1240	2.1	33	ASHCROFT	182	3	1.43
24	F	OCT.7	1410	0.0	22	YALE	0	0	0.00
		OCT.8	1015	20.1	11	YALE	18	18	0.90
		OCT.9	1010	23.9	4	YALE	29	11	0.46
		OCT.11	1000	47.8	91	ASHCROFT	90	61	1.28
		OCT.11	1530	5.5	89	ASHCROFT	94	4	0.73
		OCT.12	935	18.1	77	ASHCROFT	112	18	0.99
		OCT.12	1200	2.4	74	ASHCROFT	117	5	2.08
		OCT.13	1325	25.4	57	ASHCROFT	144	27	1.06
		OCT.14	830	19.1	45	ASHCROFT	163	19	0.99
		OCT.14	1630	8.0	38	ASHCROFT	174	11	1.38

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN MP	RAIL /SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
25	F	OCT.7	1420	0.0	22	YALE	0	0	0.00
		OCT.8	1020	20.0	22	YALE	0	0	0.00
		OCT.9	1035	24.3	10	YALE	19	19	0.78
		OCT.11	1310	50.6	114	ASHCROFT	53	34	0.67
		OCT.12	1005	20.9	104	ASHCROFT	69	16	0.77
		OCT.13	1500	28.9	88	ASHCROFT	94	25	0.87
		OCT.14	915	18.3	77	ASHCROFT	112	18	0.98
		OCT.15	1515	30.0	53	ASHCROFT	150	38	1.27
		OCT.16	1100	19.8	39	ASHCROFT	174	24	1.21
26	F	OCT.7	1425	0.0	22	YALE	0	0	0.00
		OCT.8	1020	19.9	17	YALE	8	8	0.40
		OCT.9	1010	23.8	3	YALE	30	22	0.92
		OCT.11	1300	50.8	92	ASHCROFT	90	60	1.18
		OCT.12	935	20.6	77	ASHCROFT	112	22	1.07
		OCT.13	1325	27.8	57	ASHCROFT	144	32	1.15
		OCT.14	830	19.1	45	ASHCROFT	163	19	0.99
		OCT.15	1515	6.8	37	ASHCROFT	176	13	1.91
27	M	OCT.7	1430	0.0	22	YALE	0	0	0.00
		OCT.9	1010	43.7	8	YALE	22	22	0.50
28	M	OCT.7	1440	0.0	22	YALE	0	0	0.00
		OCT.8	1020	19.7	22	YALE	0	0	0.00
		OCT.9	1010	23.8	12	YALE	16	16	0.67
		OCT.11	1445	52.6	0	YALE	35	19	0.36
		OCT.12	1015	19.5	112	ASHCROFT	56	21	1.08
		OCT.13	1345	27.5	95	ASHCROFT	83	27	0.98
		OCT.14	920	19.6	91	ASHCROFT	90	7	0.36
		OCT.15	1545	30.4	88	ASHCROFT	94	4	0.13
		OCT.16	1010	18.4	88	ASHCROFT	94	0	0.00
		OCT.17	940	23.5	81	ASHCROFT	107	13	0.55
29	F	OCT.7	1510	0.0	22	YALE	0	0	0.00
		OCT.8	1020	19.2	22	YALE	0	0	0.00
		OCT.9	1040	24.3	4	YALE	29	29	1.19
		OCT.11	1510	52.5	95	ASHCROFT	83	54	1.03
		OCT.12	945	18.6	89	ASHCROFT	93	10	0.54
		OCT.12	1145	2.0	89	ASHCROFT	93	0	0.00
		OCT.13	1520	27.6	70	ASHCROFT	123	30	1.09
		OCT.14	840	17.3	59	ASHCROFT	141	18	1.04
		OCT.14	1630	7.8	52	ASHCROFT	152	11	1.41
30	M	OCT.7	1515	0.0	22	YALE	0	0	0.00
		OCT.8	1015	19.0	12	YALE	16	16	0.84
		OCT.9	1005	23.8	2	YALE	32	16	0.67
		OCT.11	1500	52.9	99	ASHCROFT	77	45	0.85
		OCT.12	1000	19.0	98	ASHCROFT	78	1	0.05

APPENDIX I. SOCKEYE RADIOTELEMETRY MONITORING IN THE FRASER/THOMPSON RIVERS

FISH NO.	SEX	DATE	OBSERVED TIME	ELAPSED TIME(HR)	CN RAIL MP	/SUBDIV.	RIVER KM	DISTANCE IN KM	RATE KM/HR
31	F	OCT.10	1650	0.0	22	YALE	0	0	0.00
		OCT.12	1100	42.2	8	YALE	22	22	0.52
		OCT.14	940	46.7	112	ASHCROFT	56	34	0.73
32	F	OCT.10	1650	0.0	22	YALE	0	0	0.00
		OCT.11	1430	21.7	20	YALE	3	3	0.14
		OCT.12	1030	20.0	10	YALE	19	16	0.80
		OCT.14	940	47.2	114	ASHCROFT	53	34	0.72
		OCT.15	1550	30.2	92	ASHCROFT	90	37	1.23
		OCT.16	1015	18.4	88	ASHCROFT	94	4	0.22
33	M	OCT.10	1650	0.0	22	YALE	0	0	0.00
		OCT.11	1430	21.7	22	YALE	0	0	0.00
		OCT.12	1030	20.0	7	YALE	24	24	1.20
		OCT.13	1440	28.2	11	ASHCROFT	58	34	1.21
		OCT.14	930	18.8	97	ASHCROFT	80	22	1.17
		OCT.15	1545	30.3	88	ASHCROFT	94	14	0.46
		OCT.16	1030	18.8	76	ASHCROFT	114	20	1.06
		OCT.16	1700	6.5	71	ASHCROFT	122	8	1.23
		OCT.17	915	16.3	57	ASHCROFT	144	22	1.35
		OCT.17	1820	9.1	47	ASHCROFT	160	16	1.76
		OCT.18	1030	16.2	33	ASHCROFT	182	22	1.36
34	F	OCT.10	1735	0.0	22	YALE	0	0	0.00
		OCT.12	1100	41.4	10	YALE	19	19	0.46
		OCT.13	1440	27.7	114	ASHCROFT	53	34	1.23
		OCT.14	930	18.8	99	ASHCROFT	77	24	1.28
		OCT.15	1540	30.2	79	ASHCROFT	109	32	1.06
		OCT.16	1000	18.3	73	ASHCROFT	118	9	0.49
		OCT.16	1705	7.1	67	ASHCROFT	128	10	1.41
		OCT.17	915	16.2	55	ASHCROFT	146	18	1.11
		OCT.17	1800	8.8	47	ASHCROFT	158	12	1.36
		OCT.18	1115	17.3	34	ASHCROFT	182	24	1.39
		OCT.18	1400	2.8	31	ASHCROFT	187	5	1.79

APPENDIX II

Detailed Observations

of Radio Tagged Sockeye

1982

Appendix II Detailed Observations of Radio Tagged Sockeye, 1982.

Fish	Date	CN MP Location	Time	Comments on Fish Location
3	Oct. 01	50.0	0900	Located from air
		49.1	0945	
		48.3	1045	
		47.8	1125	Left bank u/s of Bonaparte R.
		47.3	1135	Fish on left bank
		47.1	1155	CN bridge - left bank
		45.8	1345	Right bank
		43.0	1600	Located from air
4	Oct. 01	54.2	1620	Immediately below slide site
		53.0	1645	Moved quickly through slide site
		52.6	1655	Assume fish on right bank
5	Oct. 01	50.0	0900	Located from air
		48.5	1015	
		48.0	1025	
		47.1	1100	Left bank at bridge
		45.8	1310	Appeared to cross left to right
		45.5	1330	Assume on left bank
		42.0	1600	Located from air
6	Oct. 02	78.0	0910	Located from air
		74.0	1220	
		73.1	1430	Located on right bank
		73.0	1445	Right bank
8	Oct. 02	88.0	0915	Located from air
		87.5	1020	Left bank
		87.4	1030	Left bank
		87.3	1040	Left bank
		85.0	1220	
9	Oct. 02	79.0	0910	Located from air
		76.0	1220	
		74.0	1320	Right bank
		74.0	1400	Right bank
		73.5	1505	Opposite Nicola River
		73.0	1530	
	Oct. 04	50.0	0910	Located from air
		49.0	0945	Left bank
		48.2	1040	Left bank - visual sighting
		47.8	1055	
		47.2	1115	
		46.9	1140	

Appendix II Detailed Observations of Radio Tagged Sockeye, 1982. (Cont'd).

Fish	Date	CN MP Location	Time	Comments on Fish Location
10	Oct. 05	79.0	0945	Located from air
		76.5	1145	Left bank
		75.1	1315	Left bank
		74.5	1345	Left bank
		73.5	1525	
		73.2	1550	Right bank
		73.0	1610	
		72.3	1640	
11	Oct. 09	47.0	0840	Located from air
		47.4	1020	Left bank
		47.3	1040	Crossed from left to right bank
		47.0	1055	Right bank
		46.5	1145	Right bank
		45.9	1245	Left bank - may have crossed at bridge
		45.3	1320	Left bank
		44.4	1405	Left bank
12	Oct. 09	76.0	0930	Located from air
		75.0	1415	Right bank
		74.3	1445	Right bank
		73.5	1530	Mid-channel - fishermen noted on right bank
		72.9	1730	Right bank - visual sighting
	Oct. 12	36.5	0900	Located from air
		34.5	1110	Right bank
		33.5	1330	Right bank
		32.6	1420	Crossed to left bank
		32.4	1435	Left bank
		32.2	1440	Left bank
		32.0	1445	Left bank - visual sighting
		31.8	1500	Left bank - visual sighting
14	Oct. 05	65.0	1210	
		65.1	1220	Right bank
		65.0	1230	Right bank
		64.0	1320	Right bank
		63.6	1330	Right bank
15	Oct. 08	49.0	0900	Left bank
		48.0	0945	Left bank
		47.9	0950	Left bank - visual sighting
		47.8	1000	Left bank - visual sighting
		47.5	1010	
		47.2	1025	

Appendix II Detailed Observations of Radio Tagged Sockeye, 1982. (Cont'd).

Fish	Date	CN MP Location	Time	Comments on Fish Location
15	Oct. 08	46.9	1040	
		46.8	1100	Left bank
		46.6	1130	
16	Oct. 07	89.0	0955	
		88.5	1215	
		85.6	1530	
		85.2	1705	
		85.0	1835	
	Oct. 08	76.0	1100	Located from air
		75.0	1210	Crossing left to right?
		74.8	1245	Right bank
		73.7	1430	Right bank
		73.1	1600	Right bank
	Oct. 10	56.0	0940	Located from air
		54.9	1140	Left bank - visual sighting
		54.8	1200	Left bank
		54.5	1230	
		54.2	1245	Crossing to right bank
		53.9	1300	Crossing to left bank
		53.7	1315	Left bank
		53.6	1330	Crossed to right bank
		53.3	1400	Right bank
		53.2	1415	Mid-channel
		53.2	1420	Left bank
		51.5	1625	Left bank - visual sighting
		51.3	1640	Left bank - visual sighting
		51.2	1655	
		50.9	1730	Right bank
		50.7	1735	Left bank
17	Oct. 10	76.0	0950	Located from air
		73.7	1310	Left bank
		73.4	1335	Left bank
		73.3	1345	
18	Oct. 09	41.0	0900	Located from air
		39.0	1045	Right bank
		38.8	1100	Right bank
		37.8	1210	Right bank
		37.8	1230	Right bank
		36.0	1345	Right bank
		35.8	1405	Right bank
		34.8	1440	Right bank
		33.8	1540	Left bank
		33.5	1555	Right bank
		33.0	1625	

Appendix II Detailed Observations of Radio Tagged Sockeye, 1982. (Cont'd).

Fish	Date	CN MP Location	Time	Comments on Fish Location
20	Oct. 12	59.5	0930	Located from air
		57.0	1200	
		53.0	1600	
		51.5	1730	
22	Oct. 13	49.0	1050	
		48.5	1100	Left bank
		47.9	1130	
		47.3	1200	
		46.2	1300	Crossing to right bank
		45.9	1410	Crossing to left bank
		44.0	1600	Left bank
23	Oct. 14	35.0	1035	Right bank
		34.5	1105	Left bank
		34.0	1130	Left bank
		33.5	1205	Left bank
		33.0	1240	Left bank
24	Oct. 14	45.0	0830	Located from air
		42.5	1030	Located from air
		42.5	1140	Right bank
		41.0	1250	Right bank
		39.6	1340	Right bank
		39.3	1415	Crossed to left bank
		38.9	1435	Crossed to right bank
		38.0	1540	
		37.9	1615	
		38.0	1620	
26	Oct. 14	45.0	0830	Located from air
		42.0	1030	Located from air
		42.0	1110	Right bank
		38.7	1445	Right bank
		37.2	1515	Right bank
29	Oct. 14	58.5	0840	Located from air
		57.0	1020	Located from air
		56.5	1100	Left bank
		56.4	1110	Left bank
		56.1	1130	Left bank
		56.0	1140	Crossed to right bank
		51.5	1630	
33	Oct. 16	76.0	1030	Located from air
		73.8	1300	Left bank
		73.5	1330	Left bank - visual sighting

Appendix II Detailed Observations of Radio Tagged Sockeye, 1982. (Cont'd).

Fish	Date	CN MP Location	Time	Comments on Fish Location
33	Oct. 16	73.4	1340	Mid-channel
		72.5	1515	Left bank
		71.5	1615	Left bank
		70.5	1700	Located from road
	Oct. 17	56.5	0915	Located from air
		56.0	1100	Located from air
		53.0	1225	Left bank
		52.5	1245	
		52.2	1300	
		51.9	1315	Left bank
		51.5	1345	
		51.4	1355	Left bank
		50.3	1455	Left bank
		47.8	1700	Left bank
		47.3	1740	Left bank
		47.0	1805	Left bank
		46.8	1820	Left bank
34	Oct. 16	73.0	1000	
		70.0	1300	
		67.5	1630	
		67.0	1700	Right bank
		66.9	1705	Small channel next to rail grade
	Oct. 17	55.3	0915	
		54.5	1100	Located by air
		53.2	1140	
		53.0	1215	
		52.3	1235	Mid-channel
		51.9	1255	Left bank
		51.5	1325	Left bank at rapids
		51.4	1330	Left bank
		50.3	1440	Left bank
		48.0	1700	Left bank
		47.4	1740	Left bank
		47.2	1800	Left bank
	Oct. 18	33.5	1115	Right bank
		33.2	1130	Right bank
		33.0	1145	Right bank
		32.1	1245	Left bank
		32.0	1255	Left bank
		31.6	1325	Left bank
		30.8	1400	Left bank

APPENDIX III

Thompson River Discharge

1982

Appendix III

THOMPSON RIVER DISCHARGE - 1982

THOMPSON RIVER NEAR SPENCES BRIDGE - STATION NO. 08LF0 51

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	DAY
1	278	254	239	224	385E	2190	2720	1690	982	748	573	351	1
2	265	254	238	224	412E	2250	2690	1740	984	733	566	358	2
3	256	253	237	225	439A	2340	2700	1860	972	709	560	364	3
4	244	249	234	226	458A	2440	2700	1970	970	705	550	366	4
5	229	248	236	226	475A	2510	2730	1990	974	718	539	367	5
6	224B	249	237	227	492A	2570	2820	1920	1030	720	530	358	6
7	224	245	237	227	516A	2600	2870	1820	1100	701	523	351	7
8	224	241	236	228	546E	2570	2840	1730	1120	682	515	342	8
9	226	235	236	229	581E	2490	2740	1650	1100	675	504	329	9
10	231	233	236	231	614A	2420	2620	1590	1090	668	495	319	10
11	235	228	235	231	682A	2390	2510	1540	1160	652	482	312	11
12	247	227	234	235	742A	2410	2410	1540	1240	636	471	307	12
13	256	227	233	235	800A	2500	2330	1570	1230	623	459	303	13
14	264	226	233	235	886	2610	2260	1590	1190	613	451	302	14
15	263	227	231	238	982	2720	2220	1590	1140	610	441	307	15
16	271	230	230	243	1110	2830	2260	1580	1080	606	436	312	16
17	271	236	230	249	1250	2920	2310	1550	1010	602	429	313	17
18	269	240	229	250	1380	2990	2270	1500	958	608	423	313	18
19	266	240	228	252	1520	3010	2230	1440	911	614	417	313	19
20	262	242	227	253A	1670	3010	2240	1380	870	614	412	309	20
21	259	244	225	257A	1770	3010	2270	1320	837	608	403	308	21
22	255	244	224	257A	1840	3010	2290	1250	813	598	393	305	22
23	254	243	225	261A	1900	3040	2250	1210	791	592	379	300	23
24	252	238	223	270E	1990	3080	2190	1170	770	586	361	295	24
25	252	241	223	279E	2090	3090	2120	1140	759	584	348	295	25
26	253	240	222	288A	2140	3040	2040	1100	739	593	343	288	26
27	253	239	222	304A	2210	2970	1930	1060	730	592	344	283	27
28	255	237	223	323A	2260	2880	1850	1030	721	592	342	277	28
29	256		223	340A	2240	2820	1790	1010	730	586	344	270	29
30	256		224	358A	2200	2770	1750	999	745	586	345	261	30
31	255		225		2180		1710	986		583		259	31
TOTAL	7806	6710	7135	7625	38762	81480	72660	45515	28746	19737	13378	9737	TOTAL
MEAN	252	240	230	254	1250	2720	2340	1470	958	637	446	314	MEAN
DAM3	674000	580000	616000	659000	3350000	7040000	6280000	3930000	2480000	1710000	1160000	841000	DAM3
MAX	278	254	239	358	2260	3090	2870	1990	1240	748	573	367	MAX
MIN	224	226	222	224	385	2190	1710	986	721	583	342	259	MIN

A-MANUAL GAUGE
B-ICE CONDITIONS
E-ESTIMATED